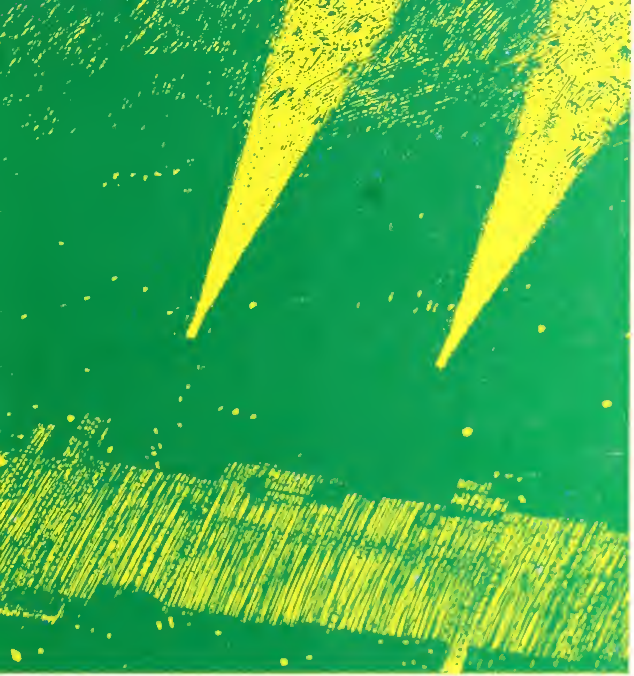


5

The Macmillan Science Series

Science for Tomorrow's World

Teachers' Annotated Edition

THE MACMILLAN SCIENCE SERIES A NINE-BOOK SERIES FOR ELEMENTARY SCHOOLS

SCIENCE FOR TOMORROW'S WORLD, BOOK 5

YOUR TEACHERS' ANNOTATED EDITION PROVIDES:

- *A Teachers' Guide, bound into the back of the textbook*

The Content and Process of Science Education (see guide pages 7 to 22)—This overview of science education in today's elementary schools explains the philosophy behind THE MACMILLAN SCIENCE SERIES, with emphasis on the *structure of subject matter* in the science curriculum and the *conceptual framework* of the series.

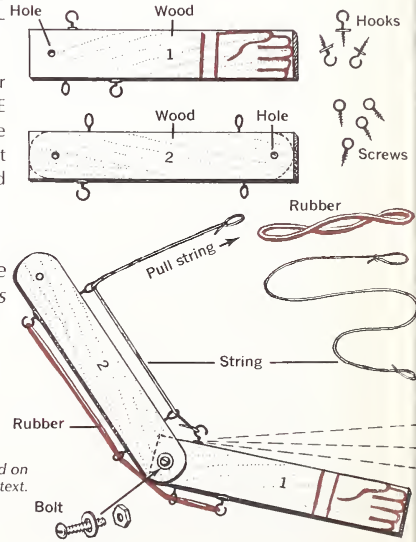
How Children Acquire Science Knowledge: A Developmental Approach (see guide pages 23 to 31)—Here is a practical discussion of the relationship between the teaching of science and the development of logical thought processes.

Some Problems of Method in Teaching Science (see guide pages 32 to 61)—This part of the guide covers such important topics as providing for individual differences and using community resources.

Overviews, Tests, and Directories (see guide page 62)—Here are overviews for each unit in the book plus the table of contents of each book in the SCIENCE FOR TOMORROW'S WORLD, BOOKS 1-6, series to appraise you of the place of your book in the series structure. This section also includes tests for each unit in the textbook and directories of publishers, film and filmstrip sources, and suppliers of source materials.

- *The Pupils' Textbook, with teaching suggestions printed beside the text pages and with annotations printed right on the text pages*

Fully developed lesson plans | Background information | Additional activities and demonstrations | Readings for the pupils and the teacher | Answers to the questions in the textbook | Checklist of science materials



An activity suggested on page 121 of the text.

SOME OF THE SPECIAL FEATURES YOU'LL FIND IN BOOK 5:

Units organized to teach the Key Concepts of science

SCIENCE FOR TOMORROW'S WORLD, BOOK 5, is built on the 10 Key Concepts of science that are described on pages 12–18 in the Teachers' Guide. Throughout the text, specific concepts lead the pupils toward deeper understanding of these Key Concepts. Unit 4, for example, helps pupils to understand:

The Key Concepts

When equilibrium is upset in organism-environment interactions, regulatory mechanisms go to work to restore equilibrium.

There is a relationship between structure and function; the structure of parts of living organisms determines the function of those parts.

Some of the Specific Concepts

1. All forms of life must carry on certain activities to stay alive (page 80).

2. The circulatory system maintains a suitable environment for cells of the body (pages 80-87).

3. Through digestion, food is prepared for use by cells of the body (pages 87-91).

4. Through the respiratory system, oxygen is supplied to the blood and CO_2 removed (pages 92 and 93).

5. The excretory system removes wastes from the body (pages 93-95).

6. Muscles and bones make it possible for the body to move (pages 96-98).

7. Living things adjust to changes (pages 100-118).

8. The nervous system controls body actions and helps maintain homeostasis (pages 101-115).

Lessons, activities, and illustrations that teach pupils to think and work using the ways of the scientist.

SCIENCE FOR TOMORROW'S WORLD, BOOK 5, provides numerous insights into the ways in which scientists think and work. Unit 6, for example, teaches the pupils to work out problems by:

Observing (pages 168, 169, 172, 174-188, 191, 193, 195-199, 202, 208, 209)

Experimenting (pages 170-172, 174-178, 180, 186-188, 193, 197)

Measuring (pages 170-177, 180, 183-186, 195, 197, 209)

Classifying (pages 169, 189-191, 201)

Demonstrating (pages 172, 174, 179, 180, 183, 187, 188, 193, 199)

Comparing (pages 172, 173, 175, 178, 180-183, 186-188, 191, 193, 195, 196, 202, 209)

Inferring (pages 172, 175, 176, 178, 180, 183, 186, 188, 191, 193, 195, 197, 198, 203, 205)

Explaining (pages 171, 172, 174-176, 178, 180, 183, 186-188, 193, 197, 198, 202, 205, 209)

Hypothesizing (pages 170, 171, 175, 180, 186, 193, 197, 209)

For more special features, turn to the inside back cover.

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HEALTH CONSULTANT

UNDER THE EDITORSHIP OF
SIDNEY SELTZER

SCIENCE FOR TOMORROW'S WORLD: 1, 2, 3, 4, 5, 6
SCIENCE: A SEARCH FOR EVIDENCE 7
SCIENCE: A WAY TO SOLVE PROBLEMS 8
SCIENCE: A KEY TO THE FUTURE 9

Texts, Teachers' Annotated Editions, and other Complementary
and Supplementary Teaching Materials

TEACHERS' ANNOTATED EDITION

The TEACHERS' ANNOTATED EDITION consists of

- Teaching Suggestions
- Annotated text pages
- Teachers' Guide

THE MACMILLAN SCIENCE SERIES

Science for Tomorrow's World

5

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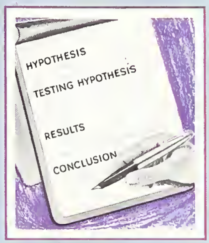
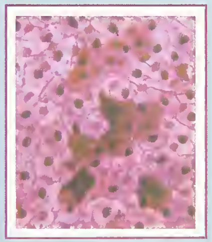
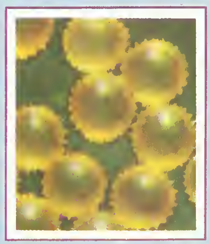
What's Ahead?

CONTENTS







ABOUT THE TEACHING SUGGESTIONS

Teaching Suggestions, for each page in the pupil's textbook, are found on the outside of the page. The Teaching Suggestions include lesson plans, background material, the answers to the questions posed in the pupil's pages, additional activities, and bibliographies of books and films. The suggestions apply directly to the material on the pupil's pages and provide a ready reference for the teacher as he or she uses the textbook in class. Many pages have space on them for teachers to write in their own comments. A Materials Checklist is included in each book, containing ample space for teachers to add materials for experiments and demonstrations of their own.

PROFESSIONAL BOOKS FOR TEACHERS

Blough, Glenn O., *It's Time for Better Elementary School Science.* NSTA, 1958. 48 pp. Of special interest to administrators and supervisors. Theory for science curriculum construction.

Brandwein, Paul F., Fletcher G. Watson, and Paul E. Blackwood. *A Book of Methods.* New York: Harcourt, Brace, 1958. 568 pp. An excellent sourcebook.

Deason, Hilary J., *Science Booklist for Children,* American Association for Advancement of Science, and NSF, Washington, D.C., 1960. 138 pp.

Hone, Elizabeth B., and Alexander Joseph, Edward Victor, and Paul F. Brandwein. *A Sourcebook for Elementary Science.* New York: Harcourt, Brace & World, 1962, 552 pp. An excellent sourcebook.

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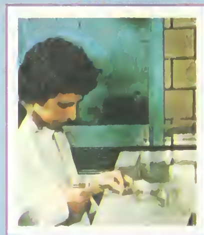
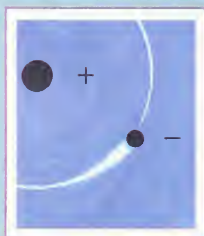




California Journal of Elementary Education, Vol. 21, No. 2, November 1952. 63 pp. Special issue on science for every child and every teacher; characteristics of a good program, equipment, and materials.

Leadership for Science in the Elementary Schools. California Association for Supervision and Curriculum Development, 1960. 88 pp. A handbook for teachers, administrators, consultants, and supervisors.

Looking Ahead in Science. California State Department of Education, 1960. 88 pp. Report of the Production Seminar and Conferences on the Improvement of Science Education in the Elementary School Purposes, appropriate experiences and content, equipment and materials, scheduling, evaluation, pre- and in-service education.

Safety Through Elementary Science. Washington, D.C.: National Education Association, 1949.

Theory Into Action. NSTA, 1964. 48 pp. Discusses science curriculum development based on conceptual schemes.

UNESCO: Source Book for Science Teaching. New York: UNESCO, 1959. This volume has been revised, expanded, and reprinted in many editions.

KEY CONCEPTS

Key Concept 1. Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

Key Concept 9. The scientist has developed measures of space, time, and matter so that he can communicate explanations that are reproducible and make predictions about events in the natural environment.

CONCEPTS:

1. Hypotheses serve as guides in conducting investigations to gather knowledge.
2. Some hypotheses eventually become scientific theories.
3. Hypotheses may be tested by experimentation.
4. Probability theory puts limitations upon predictions.
5. Scientists continue their search for better answers.

The Scientist's Way

1

Other concepts appear under "Learnings to Be Developed" in each lesson found in the Teaching Suggestions.

Testing Ideas

Ways to Get Answers

How Sure Can You Be?

PROCESSES:

- Questioning—Pages 2, 3, 5.
- Observing—5, 6, 16.
- Experimenting—5, 6, 16.
- Comparing—5, 6, 11, 16.
- Inferring—5, 6, 11, 16.
- Selecting (sources from recall)—8, 9, 10, 17.
- Communicating—13.
- Demonstrating—11.
- Explaining—2, 3.
- Hypothesizing or Speculating—2, 3, 5, 6, 7, 16.

TEACHING SUGGESTIONS
(pp. 2–3)

LESSON: How are problems solved and questions answered?

Background: Most definitions of science agree that science begins with a search for knowledge or truth about some natural event or series of events. If this is so, then a scientist sets for himself the task of finding the truth—and the methods he uses to do this are scientific methods.

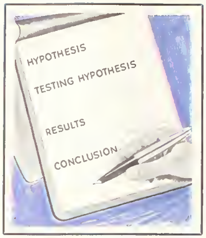
The educated guess, or hypothesis, is a rational attempt at an answer to a given problem. This lesson introduces this first step in problem solving. Hypothesis formation is an intellectual activity based on prior knowledge or, at times, pure intuition. Most people are forced to rely on the former.

The ideas given by the children on page 2 in response to the experiment that "did not work" are in effect hypotheses. They are responses to the question, "Why did the demonstration fail?" (An *experiment* never fails. It may not yield expected results, however.)

Learnings to Be Developed:

Hypotheses serve as guides in conducting investigations.

The hypotheses we make are usually based on our past learnings.



How can the weather be changed or controlled? What causes undersea waves? How can a cold-preventing vaccine be made? Science is a search for answers. Scientists are the searchers. The ideas they get in their search must always be tested. When you test your ideas, you are working like a scientist.

Ways to Get Answers

You have a question that you want answered or a problem that needs to be solved. How do you go about getting an answer? Suppose you wanted to test the idea that air can push things. You might put a piece of cardboard on top of a glass of water. Then you might turn the glass upside down. You might decide, based on what you already know, that the water will stay in the glass because the air pushes up against the cardboard and holds it there. One fifth-grade class tried the experiment, but it did not work. The water poured out of the glass. Luckily the class performed the experiment over a basin.

Their teacher asked them why the experiment did not work. Here are some of the ideas that the boys and girls had:

1. The water spilled because the glass was not turned over quickly enough.
2. The cardboard should have been thicker.
3. The boy who held the glass jiggled his hand.
4. Water is heavier than air, and it pushed the cardboard from the glass.
5. There was a little air on top of the water in the glass, and it pushed the water out.

These are some of the ways to get ideas about the world around you. Can you identify each way? Which of these ways do you use to find out about things?

Where did the boys and girls get their ideas? They got their ideas from observing, from reading, from earlier experiences, and from thinking about the problem. Scientists get their ideas and answers in the same ways.

Forming a Hypothesis

Do you think that a scientist spends all his time peering through a telescope or a microscope in a laboratory filled with gleaming equipment? A scientist often develops his ideas about problems even when he is very far away from his work in a laboratory. A trained mind and a natural curiosity about the world are a scientist's best tools.

When a scientist has a problem to solve, he puts the problem in the form of a question. Then he, alone or with other people interested in the problem, tries to arrive at an answer by observing, reading, or thinking. When a possible answer comes to mind, this is called a **hypothesis** (hy-POTH-uh-siss). The plural of *hypothesis* is *hypotheses*.

Forming a hypothesis is not the same as solving a problem. A hypothesis is simply a guess about the answer to a problem. It is the first step in finding the answer. Next, the hypothesis must be tested to see if it really is the correct answer, if it really does solve the problem.

Developing the Lesson: The lesson can begin by a reading of page 2 of the text.

- *Where did the children get these five ideas?* (From their observations: they saw what happened and gave an interpretation—answers 1 and 3; from earlier experiences: they had performed the experiment before, or had seen it demonstrated, and had noted why it had previously failed—answers 1, 2, 3, and 5; from reading: they understood the theory behind the experiment and were aware of the problems that might be encountered—answers 4 and 5.)
- *Why are these hypotheses?* (Read page 3. They are responses to the question or problem, "Why did the demonstration not work as expected?")
- *Are all the five responses true?* (No.)

Only a "replay" of all the conditions and accurate recording would allow the children to single out for study the experimental factor (See Unit 1, Book 4).

TEACHING SUGGESTIONS
(pp. 4–5)

LESSON: How are hypotheses useful in everyday life?

Learnings to Be Developed: Making hypotheses is a natural activity of the human mind.

Developing the Lesson: A typical experience can be utilized to emphasize the point that the children probably form and test hypotheses every day. When you go into the room, flip the switch of a desk lamp from the Off to the On position. However, be sure that the bulb of the lamp is one that has already "blown out."

What should I do now?

Some will answer that you should try it again. Others may suggest that the plug is out or that the bulb is not working.

What led you to those answers? (The possibility that the switch was not fully turned to On position, plugs not "plugged in" and bulbs not working are within the common experience of children.)

What do we call such guesses? (Hypotheses.)

Can we test our hypotheses? (The three responses given above can be checked.)

Everyday Hypotheses

You form hypotheses every day about things that puzzle you, though you may not call them hypotheses. You often try to explain things to yourself. You may have a question about something you hear or read. You form a hypothesis to answer this question. But have you ever tried to figure out how your hypothesis could be tested?

Jerry had some goldfish in a tank in his room. These goldfish were about two inches long. His friend Mike looked at the fish and said, "Oh, they're nothing! You should see my goldfish. They grew

Scientists form hypotheses about things that puzzle them. What hypotheses can you form about the things you see the scientists doing?

to nine inches because they were kept in a pool outdoors all summer."

Jerry did not believe his friend. He asked this question: Can goldfish grow to be nine inches long? He formed this hypothesis: No, goldfish do not grow any bigger in an outdoor pool than in an indoor tank. Therefore, Mike's fish are not goldfish. How do you think Jerry's hypothesis could be tested?

Here are some other problems:

1. How do dogs know when a cat is nearby? Billy says that all dogs are nearsighted and usually do not see cats. They smell them. How could you find out if Billy is right?

2. The kindergarten class has asked the fifth grade to help in wiring the kindergarten doll house for electric lights. Some of the pupils say they can make brighter lights by using more than one dry cell. How can their hypothesis be tested?

3. A fifth-grade boy is trying to decide what kind of suit is best for astronauts who go to the moon. He thinks an asbestos suit would be best. How can his hypothesis be tested?

Which of these hypotheses could you test yourself? Which ones sound like wild guesses?

To form good hypotheses, you have to know something about the problem. To form a good hypothesis about astronauts' moon suits, you need to know what it is like on the moon. Is there air on the moon? Is it hot? Is it cold? Is there sound? Is there gravity? Later in this book you will learn something about space and the moon. Then you may be able to make a good hypothesis about moon suits and how they will have to be designed.

Testing a Hypothesis

In modern science a hypothesis must be tested many, many times before it is accepted as fact. Certain rules for testing a hypothesis have been developed. What are some of these rules?

People once believed that heavy things fall faster than light ones. You can do an experiment to test this hypothesis. Before you experiment, you must make a plan.

First you must decide what you are going to drop. You must decide on the shapes and weights of the things you will drop. Then you must decide how many objects you will drop. You may decide to drop two things.

How far will you drop the things? Why should both things be dropped from the same height? How will you

Possible answers to queries on this page are:

Two propositions that might explain the phenomenon are size of pool and the location of pool. These might be combined as follows: It is size of pool and not its location; It is location of pool and not its size; It is both; It is neither. Teaching pupils the process for combining propositions helps foster the propositional thinking described on pp. 26-27 of the *Teachers' Guide*.

Billy has a double hypothesis: nearsightedness and keen sense of smell. A single experimental factor must be tested at a time. Reading research would be necessary to learn about dogs' vision limitations, since it would be impossible for him to study all dogs. A few instances of smell study could be performed by blindfolding dogs, but again his results would yield only partial answers.

The children could wire the doll house using more than one dry cell on one set of lights (for one room, or half the house) and a single cell on another set.

The conditions of heat, light, cosmic radiation, and gravity of the moon would have to be known and duplicated before a suit could be tested. Then many materials would have to be tested before any one could be declared "best."

TEACHING SUGGESTIONS
(pp. 6–7)

LESSON: What is a theory?

Background: Probably no scientist of our generation is better known than Albert Einstein. Einstein's choice of a title, the *theory* of relativity, implies a certain amount of reservation. In his theory he proposed what seemed to him, at the time, to be valid conclusions. Ever since the publication of his theory, experiment after experiment has been designed to test its validity. Each time the theory has come out intact. *Yet it is still referred to as a theory.*

Learnings to Be Developed: Some hypotheses eventually become scientific theories.

Developing the Lesson: Using the text sequence, build up the idea that after a hypothesis is proven by many means and under many circumstances by many scientists, it may become a theory. A theory is usually formed to express a general rule proved valid for many instances.

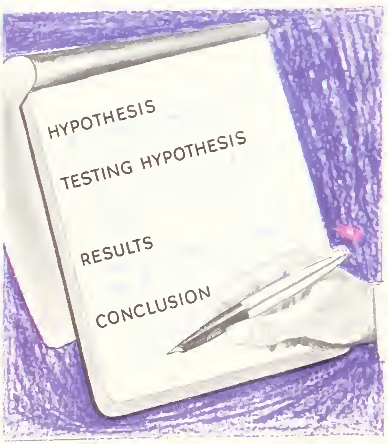
The *cell theory* is a concept that was a natural development of the work of thousands of researchers in many fields. Review the work of Schleiden, Schwann, and others.

make sure that they are dropped from the same height?

Should both things be dropped at the same time? Can you tell when they hit the ground just by watching them? Would it be better to listen for the sound they make when they hit the floor?

Finally, you must decide how many tests you should make. Is one test with two things enough? If not, how many tests with how many things are needed?

When you have decided what plan you will follow, write it out. The report of your experiment should include: (1) what your question was and a statement of your hypothesis; (2) a description of the plan you used to test the hypothesis; (3) what you found out; (4) your conclusion—whether the experiment seemed to prove or disprove your hypothesis.



Hypothesis and Theory

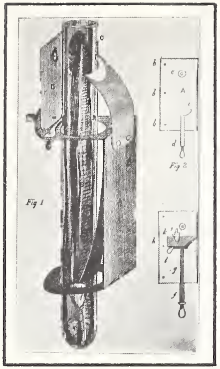
Sometimes a scientist forms a hypothesis as a result of his own research. At other times a scientist forms a hypothesis from information that other scientists have gathered. For example, here is an important hypothesis which is accepted today: All living things are made up of cells. This hypothesis is the result of the work of two German scientists, Matthias Schleiden (SHLY-den) and Theodor Schwann (SHVON). They formed the idea from the reports of other scientists.

As you know, a microscope can be used to see very small things. Before it was invented, no one knew that there were tiny plants and animals too small to be seen by the eye alone.

About three hundred years ago, a Dutch scientist named Anton van Leeuwenhoek (LAY-vun-hook) invented a microscope and with it saw tiny animals in water. Another scientist saw tiny, boxlike compartments in certain plants; he called the compartments cells. With the aid of the microscope, more and more was found out about cells. Each scientist reported to other scientists about his discoveries.

In the nineteenth century, Schleiden and Schwann read the reports of these other scientists. As they read, they

Work out a plan for your pupils to keep science notebooks



This picture shows Anton van Leeuwenhoek and one of the microscopes he made. Can you tell how the microscope worked? How would you go about finding out?

formed the hypothesis that *all* living things are made up of cells. They checked the reports of still other scientists. Of course, they could not examine all the different kinds of plants and animals that were found in the world. But they did make many observations that led them to their idea.

This hypothesis has been tested over and over by other scientists. The results were always the same. A hypothesis such as "All living things are made up of cells" is called a **theory** (THEE-uh-ree). A theory tries to show the connection among many facts. All living things, from the smallest one-celled plant or animal to the largest, are made up of cells. This is the **cell theory** of living things.

Einstein and the Atom

Scientists get their ideas and form their hypotheses by observing, studying, and thinking. Fine laboratories and books help, but a theory really comes from the scientists' minds.

Albert Einstein (YN-styn), one of the greatest scientists who ever lived, formed a very important theory about the universe. The tool with which he worked was not expensive laboratory equipment, but mathematics. A hypothesis about the universe cannot be tested in the same way that a hypothesis about cells can be tested. Can you tell why? Scientists who understand Einstein's mathematics accept his theory.

You have already learned that everything in the universe is made up of

The work of Einstein mentioned on page 7 is a good example of the fact that not all science knowledge is arrived at by manipulating equipment and doing experiments.

○ **ADDITIONAL ACTIVITIES:**

Purchase at least a dozen baby goldfish. Have the children put the goldfish into three groups. Group 1 remains in the original tank of water, which is placed outdoors. Group 2 is placed outdoors in a tank of fresh water. The tank must stand at least a full day before the goldfish are placed in it, to permit the water to lose any dissolved chlorine and to allow it to attain the same temperature as that of the original tank water. Group 3 is treated as group 2, but remains indoors. Reasons: for group 1, there may be a factor in the original water that inhibits growth; for groups 2 and 3, now that the water is eliminated as a variable in the experiment, we can test the tank's position.

Have the class form a hypothesis about problem 2 on page 5 and test it. (For example: "Two or more dry cells will give a brighter light than one dry cell.") A device to measure the intensity of the light is needed.

TEACHING SUGGESTIONS
(pp. 8–10)

● LESSON: What other ways help us find answers to questions?

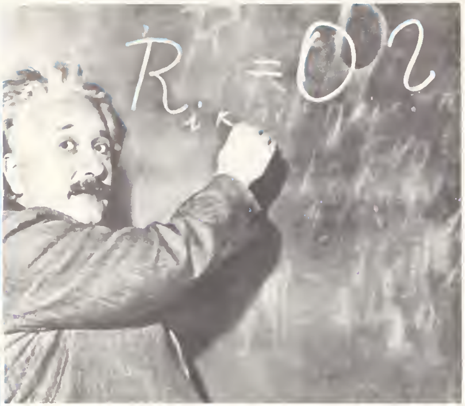
Learnings to Be Developed:

Hypotheses are tested by further experimentation.

When it is not practical to test an idea yourself, you should seek a good source of information.

Developing the Lesson: Begin the lesson by reading and discussing the section "Another Way to Get Answers."

- *What sources of information are generally available?* (Books, encyclopedias, periodicals, newspapers.)
- *How can we judge the reliability of these sources of information?* (Books: The reputation of the publisher is a guide. The author's reputation and his connections with institutions of learning or research constitute another guide. Magazines: If the magazine publishes scientific articles frequently by reputable authors, or if the authors are themselves research scientists, and if their conclusions are related to the information and are stated objectively, the magazine is probably reliable.)



Albert Einstein, a famous scientist, used mathematics to form many scientific hypotheses.

atoms. One of Einstein's mathematical theories has helped man to use energy from atoms. The first important use of this atomic energy was in warfare. Fortunately, atomic energy can now also be used for many peaceful purposes—as a source of energy in factories, in medical treatment, and in other ways that help people have a better life.

Another Way to Get Answers

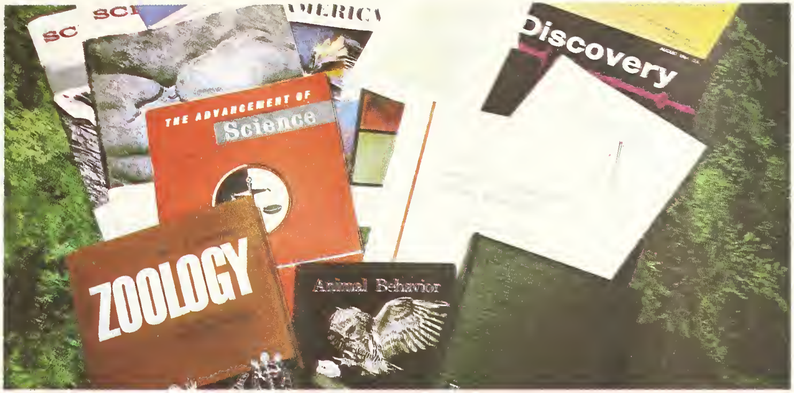
Forming and testing hypotheses is one way to get answers. But there is another way that you use every day. Perhaps Marion's problem will give you an idea of what the other way is.

Marion tried not to soil her new cotton skirt as she ate a peach. Somehow, a little juice dripped on her skirt. What could she do? She might have thought: (1) I will remove the stain with warm water and soap; (2) I will remove the stain by rubbing it; (3) I will remove the stain with cleaning fluid. Why would it not be wise for Marion to test all these hypotheses?

In this case, there was a better way to find out what to do. Marion decided to get help from a good source, so she used her mother's cookbook. Under *stains*, in the index, she found *peach*. Marion read the directions: "Stretch material with stain over a bowl. Pour boiling water from a height so that it falls on stain with force. Repeat if necessary. The stain will disappear."

Marion used a very important way to get an answer. She went to a source for her answer. She did not go to a friend who might not have the information or experience. She used a reliable source, the cookbook, to help her solve the problem.

Is it always practical to test an idea yourself? Of course not. Sometimes you do not have the necessary information. Sometimes you do not have enough time or equipment. Sometimes it would be too dangerous. You can go to a reliable source for help—a source that you know has the information.



These are some of the many sources you might use to find the answers to questions you have in science. How would you decide which source to use?

How would you find the answer to the question, "Why is it hotter in your city in summer than in winter?" Suppose your hypothesis was that the temperature had something to do with the earth's path around the sun. Would you be able to test that idea easily? You would probably have to turn to a good source to find the answer. What source would you use? An encyclopedia? A newspaper? A science textbook? These may be good sources, but not all sources are good ones. Knowing where to get accurate help is important.

Using What You Have Learned

Discuss the following statements and their sources with your class. Which speaker may be called an expert on the subject on which he is speaking?

a. Dr. Anthony Wilding, professor of mathematics at Tompkins University, announced today the publication of his new book, *Why Jamie Is a Poor Reader*. He stated that if parents carefully study his book and help their children, they can be sure that their children will become good readers.

Background: A full discussion of the examples given in *Using What You Have Learned* would be very useful.

a. Dr. Wilding *could* be an expert in reading, but his credentials and his position lead one to believe that he is out of his field. A mathematician is certainly entitled to have an opinion on any subject—as is any citizen—but he can be regarded as an expert only in his particular field of study and specialization.

b. Dr. Haber probably knows what he is talking about. Since he is director of an institution devoted to the study of the physical adjustments of man to space, he knows from studies by himself and others in the institute the major medical problems of space.

c. Mrs. Lode's qualifications as an expert, on coffee or anything else, are utterly irrelevant, although they may frequently be accepted as valid.

d. Dr. Smith may be a good doctor or a poor one, but his judgment of politicians is as good as yours, at best. Since he is in the public eye, in a sense, his judgment may even be impaired by personal considerations unrelated to Mr. Palowski's abilities and achievements on the City Council.

TEACHING SUGGESTIONS
(pp. 10–12)

● **LESSON:** What do scientists mean when they say that something is probable?

Background: As the tools and techniques of modern mathematics have matured, one driving force has been the need for methods of dealing with the dynamic and transitive nature of reality—whether it is a physical event or a social interaction.

In recent years, probability processes have provided models for the study of such diverse subjects as population growth (human and bacterial), radioactive decay, tracking of satellites, forecasting weather, etc. In fact the laws of probability can be used in the analysis of any series of observations made over a period of time. Our model of the atom today is a mathematical one, based on probability.

Learnings to Be Developed: Probability theory puts limitations on predictions.

Developing the Lesson: Start the lesson by saying, "There's not a chance in the world of . . ."; to complete the sentence, make a topical reference such as "a picnic tomorrow," "the test's being postponed," or "rain this evening."

b. Dr. Heinz Haber, director of tne United States School of Space Medicine, stated that one of the major problems in space travel will be to protect the eyes of space travelers.

c. Mrs. Robert Lode, a wealthy lady from Levelton, Arizona, states that Benson's coffee is the best coffee. She says that she always serves it at her dinner parties because "it is the richest, most flavorful coffee."

d. Dr. James Smith, medical director of the Hamilton Hospital, stated today that he will vote for Mr. Anthony Palowski for City Council. He declared, "I feel Mr. Palowski has done a splendid job during his present term and should be re-elected."

How Sure Can You Be?

Jim and Tom wanted to go to the circus. Jim asked his mother if he could go. "Probably," said his mother. Jim was delighted. Tom asked his mother if he could go. "Probably," said his mother, but Tom was sad. Why did the boys have such different reactions? "When my mother says 'probably'," explained Jim, "nine times out of ten I get permission to do what I asked to do." "But when my mother says 'probably'," sighed Tom, "nine times out of ten I don't get permission."

Scientists, too, work with the idea of how probable it is that a thing will happen. But scientists are more exact in the use of the word *probable* than other people are. For example, scientists conducted an experiment feeding white rats. Fifty rats were given a certain amount of milk in their diet. Another fifty rats of the same age, weight, and health were given the same diet as the first group except that they received no milk. The rats that drank milk always gained more weight than those that did not drink milk. The scientists could predict that the amount of the extra weight increase would always be somewhere between 8 and 12 grams.

Understanding Probability Theory

Did you have milk for breakfast this morning? Will you have milk for breakfast tomorrow? You can probably be fairly sure you will because you know you have had milk in the past. But what if you are ill, or you oversleep, or your mother forgets to buy milk? You can say that while the probability you will have milk is great, you cannot be sure.

In fact, scientists say that nothing is absolutely certain to happen or not to happen. The truth of any hypothesis is only probable. How likely a thing is to happen, or its probability of happening, is often very important for a scientist to know.

Try this. Every penny has two sides. One side is called the head. The other side is called the tail. If you toss a penny into the air, there is an equal chance that it will land with its head or its tail facing up. Mathematicians say that the probability of getting a head on any toss is one chance out of two. They represent this chance by the fraction ½. The probability for getting a tail is the same.

Toss a penny ten times. Record heads and tails by making a tally in two columns. How many heads did you get? How many tails? Show the relation of heads to the ten tosses as a fraction. With ten tosses, the probability is low that there will be an equal number of heads and tails. If there is time, each person in the class should toss a penny ten times. Tally the results on a class chart. How many heads did the class get? How many tails? Show the relation of heads to the total number of tosses as a fraction. Compare this fraction with the first one. Do you find that the proportion changes with the increased number of tosses? Do the chances become greater that the number of heads will equal the number of tails?

If you were to toss a penny a thousand times, it is very probable that heads would turn up 500 times and tails would turn up 500 times. In other words, the probability is high that the number of heads would equal the number of tails.

Now test yourself to see how much you really understand about probability. On a piece of paper, write the numbers 1 through 5. Read the following sentences, and write *true* or *false* for each sentence.

1. If I get a head when I toss a penny, the next time I toss I probably will get a tail.
2. If I toss a penny 10,000 times, I probably will get 5,000 heads.

• *How sure of this can you be?*

The answers will vary. Generally, the degree of assurance will increase with the degree of control that can be exercised over the event, and vice versa. There are, therefore, two categories of events; (a) those we cause or can cause to happen, and (b) chance events, those for whose happening or not happening we cannot account. Give an example from each category. (An example of the first kind of event might be the children's having milk for breakfast tomorrow. They can have some control over the event, so they can be reasonably sure. An example of a chance event is the result of a penny toss.)

Background: Following are the answers to the *True* or *False* sentences (pp. 11–12):

1. *False*. This is known as the "gambler's fallacy." On every toss, as an individual event, there is a 50-50 chance of either heads or tails.

2. *False*. The laws of probability hold for very large numbers of events. If the student reads the number 5,000 as an exact count, then the answer will be *False*. It would be correct to expect *approximately* 5,000.

3. *True*. The probability exists.

4. *True*. The *possibility* exists, however.

5. *False*. As in number 4, the possibility is remote, but exists.

ADDITIONAL ACTIVITIES:

Here are some additional true-false statements:

1. Probability theory helps you find out the chances that an event will happen. (*True*.)

2. Probability theory tells you why things happen. (*False*.)

3. If two events have the same probability, one is just as likely to happen as the other. (*True*.)

Using only the words *high* and *low*, describe the probability of the following events:

1. Someone will give you a hundred dollars today. (*Low*.)

2. There will be a snowstorm in the Sahara Desert today. (*Low*.)

3. The next eight boys you see will be left-handed. (*Low*.)

4. At least two "heads" will result from ten tosses of a coin. (*High*.)

3. If I toss a penny 10,000 times, the probability is that the number of tails will be equal to the number of heads.

4. If I toss a penny 25 times, it is not probable that I will get heads every time.

5. If I toss a penny 25 times, it is impossible for the coin to fall on heads every time.

When you understand the answers to these questions, you are ready for the next step.

Toss two pennies into the air. Here are the possibilities:

two heads,
two tails,
one head and one tail,
one tail and one head.

Notice that there are four possibilities. Are you more likely to get two heads, or a head and a tail? You are more likely to get a combination of a head and a tail. The reason is that there are two chances in four of getting a head and a tail and only one chance in four of getting two heads. How can you write these two possibilities as fractions?

How about two tails? There is one chance in four of your getting two tails. Can you see why it is more probable that you will get a head-and-tail combination than two tails?

Now work out this probability problem. A dog has two puppies. What is the probability that both puppies will be males? What is the probability that there will be one male and one female? Two females?

Figure out the number of possibilities. In this case, there are four possibilities. Then figure out how probable each possibility is. There is one chance in four that both will be males and one chance in four that both will be females. There are two chances in four that there will be one male and one female. Scientists figure out the number of possibilities and the probable occurrence of each possibility in their experiments. This is the basis of **probability theory.**

Scientists use probability theory to make predictions. They figure out how probable it is that a certain vaccine will work. Or they predict how probable it is that a certain material will be able to resist the great amount of heat caused by the friction of the atmosphere when spaceships return to earth. They can also figure out how many people probably will get a disease.

You can now see how important probability theory is. By using probability theory, scientists can put to work their vast scientific knowledge about the world we live in.

Keeping Records

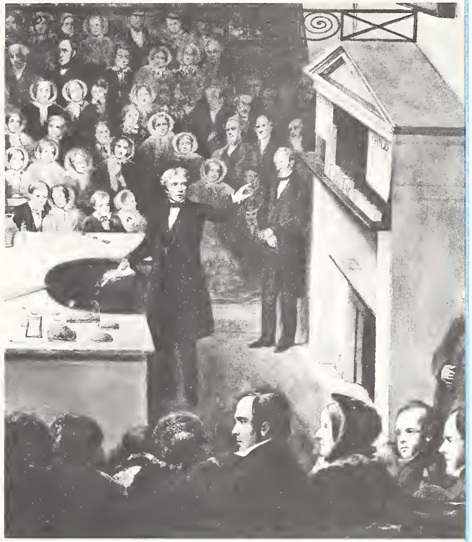
Scientists keep careful records of the ideas they have tested. These records make the results of their work available to other scientists. These records also make predictions possible.

Michael Faraday (FAR-uh-day) was an English scientist who, in the nineteenth century, discovered much about magnets. He wondered whether a coil magnet has magnetic power all the way through or just on the outside. Faraday performed experiments and kept a very careful record of what he observed. You can try his experiment just as he described it in his notebook.

"A [coil] of silked copper wire was made round a glass tube. . . . A magnetic needle nearly as long [as the glass tube] was floated with cork, so as to move about in water with the slightest impulse. The [coil] being connected with the apparatus and put into the water in which the needle lay, its ends appeared to attract and repel the poles of the needle. . . ."

In Faraday's time, there was no insulated wire. He used plain wire, wrapped with silk. Why should you use only insulated wire when you do his experiment?

After repeating Faraday's experiment, tell what happens to the needle.



Michael Faraday, whom you see speaking in the picture, kept very complete records. How has this helped later scientists?

Now bring the coil nearer to the needle. What happens as the coil is moved toward each end of the needle?

Next bring the coil very close to the end of the needle that attracts the coil. What happens? Faraday found an answer to his problem. His experiment showed that a magnet had magnetic force all the way through it.

Faraday's careful records were used by many other scientists. For example, Thomas Edison used them to help him develop the electric light.

TEACHING SUGGESTIONS
(p. 13)

LESSON: Why are records of scientific work important?

Background: An extremely important outcome of laboratory work is the ability to keep records—the ability to record data and write reports accurately and precisely.

"Make a note of all you do and all you observe," is a good direction to young pupils. Finesse and emphasis on the significant can wait until they are a bit more mature.

Learnings to Be Developed: Keeping records is important both to the scientist and to his fellow workers.

Developing the Lesson: As an exercise in record keeping, have the pupils perform Faraday's experiment on page 13. It can be done as a demonstration, but each child should be encouraged to keep his own record of procedures and observations. The record kept may be a running log of actions taken, and observations made, or it may be formalized into procedure, observations, and tentative conclusions.

Display the children's work on the bulletin board for a day or two before having them constructively criticize each other's work.

TEACHING SUGGESTIONS
(pp. 14–15)

Background: Marie Curie was born Marie Sklodowska. Both her parents had successful careers, her father as a physics teacher and her mother as principal of a girl's school, but both lost their positions following a revolt in Poland, which was then under Russian domination.

Marie had an older brother and sister who had emigrated to Paris. She worked to send them money and to save for her own eventual trip to France. She managed to make the trip in 1891, when she was 24, and immediately enrolled in the Sorbonne to study chemistry. She graduated first in her class.

Her first significant experiments on radioactivity were in measuring the amount of radioactivity emitted by different uranium ores.

Since different ores had different amounts of radioactivity, she decided that the ores must contain impurities, traces of another substance, one that was directly responsible for the radioactivity. This proved to be the case, and she and her husband discovered the elements *polonium* and, later, *radium*.

The Continuing Scientific Search

A scientist does not stop searching when he finds a good answer. There may be a better answer. For example, when gasoline engines were invented, automobiles were produced. But scientists did not stop investigating with the production of the first gasoline engine or with the first automobile. They sought to find the answers that would enable them to build engines that are easier to start. They also tried to streamline the car, to make comfortable seats, and to make safer, stronger tires.

Airplanes are another good example. The first airplane that the Wright brothers made flew a distance of about 850 feet in 59 seconds. It was made out of wood and cloth. From that simple beginning, scientists have made great strides. Airplanes can now fly at more than twice the speed of sound and more than fifteen miles above the surface of the earth.

Scientists never stop working on important problems. New facts that make the old answers incomplete are always being discovered. New answers have to be found to explain the new facts. Science is never finished with a problem. Science is not a book full of facts, but a way of using facts and testing ideas.

PATHFINDERS IN SCIENCE

Marie Curie

(1867–1934) Poland

Marie was well educated by her father. She became a teacher so that she could save money and send some to her sister in medical school. While Marie taught the children of wealthy parents, she read every book and booklet on science she could find.

By 1891, Marie had saved enough money to go to Paris to study. She lived in attic rooms for three years and ate little more than buttered bread and tea. She had discovered her lifework, science, and cared for nothing else. After her graduation, she met a French scientist named Pierre Curie. Marie went to work in his laboratory. Soon afterward they were married.

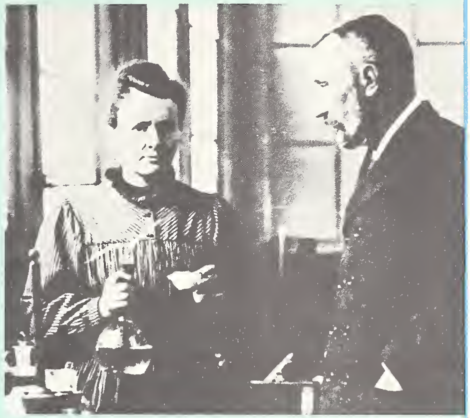
Henri Becquerel (bek-REL) had discovered that uranium ore gives off energy. He talked about his discovery with the Curies. Marie decided to do research on uranium. She made many different tests. Repeating her experiments over and over again, checking one kind of test against another, she proved that the strength of the energy given off by a piece of uranium ore was exactly equal to the amount of uranium in the ore. Her conclusion led her to a question: If uranium gives off energy, are there other elements that do the same thing? She

tested thorium. She found that thorium also gives off energy. Knowing these facts, Marie Curie stated that certain elements had what she called *radioactivity*. She invented this word, which is a familiar one today, and started an entirely new area of research in chemical and physical science.

Marie and Pierre Curie dedicated their thoughts and work for the rest of their lives to the study of radioactive elements.

In a leaky shed in a courtyard outside their office, she and her husband examined scores of untested minerals. She found that the mineral pitchblende gives off four times the amount of energy that the same quantity of uranium does. Not one of the known elements in pitchblende was radioactive. Marie came to the conclusion that pitchblende must contain one or more elements unknown to scientists. Aided by her husband, she set out to test her idea. Using every known scientific test, they separated a new element from pitchblende. They called it *polonium,* in honor of Poland.

The Curies believed that there was another unknown element in pitchblende. Again they tested their idea. In eight tons of ore they found a mere speck of the new element, *radium*. It could not even be weighed. A few years later they had one three hundredth of an ounce of pure radium! This amount would have sold for $150,000. The Curies decided to keep it



for further study, because selling it, as Madame Curie said and Pierre agreed, would be "contrary to the scientific spirit."

It was found that radium could cure certain cancers. In 1903, Marie and Pierre Curie won the Nobel Prize for the discovery of radium. In 1911, Marie Curie won a second Nobel Prize, for the extraction of radium. She is the only person to have been honored twice by the highest scientific award.

Madame Curie's daughter Irene also received a Nobel Prize in science, in 1935. However, Madame Curie did not live to see her daughter honored. Madame Curie died of a disease brought on by exposure to radium, the element she discovered for the world.

How the discovery of radium was made is itself interesting. The Curies suspected the existence of a new element because of the intense radioactivity of a small sample of refined ore they had isolated. This sample was given to a colleague, Eugene Demarçay, a chemist who specialized in spectroscopic analysis. By heating the sample and then using a spectroscope to study the spectral lines that were emitted, Demarçay was able to find formerly unknown lines that definitely established the existence of the new element.

The ore from which the Curies obtained their samples was pitchblende, from the silver mines at St. Joachimsthal, in what is now part of Czechoslovakia. The pitchblende was discarded as waste, and mounds of it lay about the mine shafts. The Curies were given all the pitchblende they wanted; all they had to do was pay the shipping charges.

Marie Curie's doctoral dissertation was an account of her and her husband's discoveries. It was for the work recounted in this dissertation—their discoveries on radioactivity—that they were awarded the Nobel Prize in 1903. Marie Curie's second Nobel Prize was for discovering polonium and radium, and isolating radium.

Marie Curie died of leukemia.

TEACHING SUGGESTIONS
(pp. 16–17)

Background: The answers to *Using What You Have Learned* are:

2a. Build a light-tight box (a shoe box will do). Cut a peephole at one end and another, smaller hole along one side to admit some light. Cut out several small pieces of cloth or paper of light and dark colors and white. With clear tape attach these papers to the inside of the box opposite the peephole. (Note: If the pupils can hear the order in which the colors are arranged they will be able to "see" better, so it is important to rearrange the order after each small group has tested it.)

2b. The humidity makes the wood swell. A handy way to overcome the sticking is by placing an electric cord with a light bulb in the sticking drawer, turning on the bulb, and allowing heat from the bulb to dry out the wood.

2c. Possibly. Some specialists think so. This would be difficult to test in class and it might be worthwhile to discuss the difficulties or variables of this kind of test.

2d. To eliminate all other possible dietary causes of curliness, we would have to feed experimental animals, or people, identical food except for addition of carrots for the experimental group.

Using What You Have Learned

1. Repeat the Faraday experiment described on page 13. This time use a floating needle that is shorter than the tube. What happens?

2. Tell if and how each of the following hypotheses could be tested. Choose two hypotheses from the list that you can test yourself. Plan experiments to test them. Carry out your experiments carefully.

a. At night, light clothing can be seen more easily than dark clothing.

b. Dresser drawers stick in the summer because heat makes things expand.

c. People can learn to spell better by studying ten minutes a day six days a week than by studying an hour one day a week.

d. Eating carrots will make straight hair curly.

e. When the sky is red in the evening, the next day will be fair.

f. Air conditioners work better when the windows are closed.

g. If you use a special wool soap to wash woolens, they will not shrink. *

h. If you drink milk, your nails will be stronger.

i. Fifth graders write more legibly on ruled paper than on unruled paper.

j. Dark clothes make people appear slim.

k. Homemade cake will stay fresh longer than cake made from a packaged mix.

l. Plastic heels wear longer than leather or rubber heels.

m. You can see better in yellow-colored light than in red-colored light.

n. Sound travels in water as well as in air.

*Temperature of the water is a significant variable in this experiment.

3. As you have learned, it is not sensible, or even possible, for boys and girls to try to find the answers to all questions by testing. But knowing where to find answers is very important. Here are some questions that boys and girls have asked. How would you go about finding the answers?

a. Is New York City bigger than London, England? *Almanac, Encyclopedia*

b. How many games did the New York Yankees win in 1965? *Almanac, Annual sports digest*

c. Does white bread have more vitamins in it than whole-wheat bread? *Encyclopedia, Nutrition books*

d. Who invented radar? *Encyclopedia, Physics textbook*

e. How much did the first man-made satellite weigh? *Recent encyclopedia*

f. Is any part of the west coast of South America farther east than part of the east coast of North America? *Globe, Atlas, Wall map, Social Studies book*

4. A penny must have all of its edge sharp if you are to have an even chance of getting a head or a tail when you toss. Why is this so? Try to find a penny that is not perfect in this respect. Toss it many times to see if an imperfect penny changes the chances.

5. Toss three coins at one time. What are all the possible results that you might get? What is the probability of getting each one? Can you express the probabilities as fractions?

6. When people travel in airplanes, they often buy air insurance. How does the probability theory affect the rates of air insurance?

7. Use the table to show how probability theory affects life insurance rates.

Age	Annual Premium for $10,000
30-34	$38.60
35-39	$52.70
40-44	$72.30

2e. Once we agree on the definition of "red sky" and "fair day," we can settle the matter by observation and record keeping.

2f. This needs no experiment. Analysis of the hypothesis will settle the matter. If you wish to condition the air in the room, you prevent, as far as possible, the removal of that conditioned air or its exchange with unconditioned air; otherwise, you will be attempting to condition the air outside as well as inside the room.

2g. Outline two clean, dry woolen socks on a piece of paper. Wash and dry the socks. Then draw another outline of the washed and dried socks. If the outlines are identical, the hypothesis is correct.

2h. Same difficulties as "d."

2i. Do not tell pupils what they are being tested for. Have each pupil write the same sentence on ruled and unruled paper, and have each pupil in the class judge all the papers as to neatness and legibility.

2j. This is a matter of subjective or individual judgment. Results of scientific tests must be objective and repeatable.

2k. Try it, after agreeing on how to judge "freshness."

2 l. Pupils can check their experience; this is not too valuable, since the data was not gathered under standardized conditions.

2m. Obtain yellow and red Christmas-tree lights and an optometrist's eye chart. Use each light individually, and make sure the distances from light to eye chart are equal. Note distances at which each can read eye chart under each light.

2n. A swimming pool would be necessary for this experiment.

3a. Encyclopedia, atlas.

3b. Almanac, general or sports.

3c. Science textbook, dietitian's handbook, or bread wrapper.

3d. Encyclopedia, science text.

3e. Encyclopedia, science text.

3f. Map.

4. Any imperfection in the penny can affect "evenness" of chances.

5. Probability of each is still 50–50. HHH, TTT, HHT, and HTT are possible results.

6. Payment based on number of accidents per passenger flown.

7. Premium increases with age.

WHAT YOU KNOW ABOUT

The Scientist's Way

What You Have Learned

Scientists have many questions about the world in which we live. They see many problems that need to be solved. Scientists have certain ways to go about solving problems and finding answers to their questions.

When a scientist has a problem to solve, he thinks of possible solutions. He puts the problem in the form of a question. Then he tries to figure out the answer by observing, reading, or thinking. He tries to make a good guess about the answer to the problem. Such a guess is called a **hypothesis.** The scientist may also form his hypothesis by putting together the information that other scientists have gathered. After he forms his hypothesis, the scientist tests it many times. Correct hypotheses about the same phenomenon may lead to a group of principles which is then called a **theory.**

Scientists say that things are not absolutely certain to happen or not to happen. How likely a thing is to happen, or the **probability** of the thing's happening, is often very important for a scientist to know. The **theory of probability** enables scientists to figure out the number of possibilities and the probable occurrence of each in their experiments. Using probability theory, scientists can plan ahead.

Hypotheses about the same phenomenon, such as gravity, may lead to a group of principles to explain that phenomenon. The group of principles is called a theory.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

hypothesis   theory   theory of probability

How Scientists Test Ideas

How did the scientists listed below test their ideas?

Jan Ingen-Housz
James Joule
Galileo
Robert Boyle

Complete the Sentence

Write the numbers 1 to 3 in your notebook. Next to each number, write the word or words that best fit the space in each sentence.

1. A good guess about the answer to a problem is called a __?__.
2. A __?__ is an attempt to explain the facts that have been discovered.
3. Scientists use __?__ __?__ to figure out the number of possibilities and the probable occurrence of each in their experiments.

Where Would You Look?

List the numbers 1 to 6 in your notebook. Next to each one write the source you would use to find the answers to these questions.

newspaper   encyclopedia   science textbook

1. How fast does sound travel in water?
2. What will the weather be today?
3. Does air pressure become lower as one goes higher in the atmosphere?
4. Who was the pioneer of American rockets?
5. How does an electron microscope work?
6. Were any rockets launched last month?

TEACHING SUGGESTIONS
(pp. 18–19)

Background: These two pages constitute a review of the concepts and terminology introduced in this unit.

What You Have Learned: This is a summary of the entire unit, with new words in boldface type.

Checklist of Science Words: Remind the students that there is a *Dictionary of Science Words* on pages 358–364. They should consult this dictionary whenever they are unsure of the precise meaning of a word.

How Scientists Test Ideas: These men are all referred to in *Science for Tomorrow's World,* Book 4. The page references below are from Book 4.

James Joule (Page 26.)
Jan Ingen-Housz (Page 64.)
Robert Boyle (Page 176.)
Galileo (Page 6.)

Complete the Sentence:

1. hypothesis
2. theory
3. probability theory

Where Would You Look?

1. Encyclopedia, science textbook
2. Newspaper
3. Science textbook
4. Encyclopedia, science textbook
5. Encyclopedia, science textbook
6. Newspaper

TEACHING SUGGESTIONS
(pp. 20–21)

Background: These pages reinforce the concepts presented in the unit by suggesting activities that extend the pupil's ability to apply the learnings derived from the unit.

Testing Hypotheses

1. *Microorganisms live in the soil.* This can be tested by placing a bit of organic matter in the soil and noting what happens to it over a period of time. It will decompose, which shows that the microorganisms have broken down its structure.

2. *Snowflakes can be photographed in freezing weather.* During a snowstorm, chill a piece of metal such as aluminum (a pie pan will do) in the refrigerator and then carry it outdoors and lay it flat. If the snow melts as it strikes the ground, the pan should be kept chilled by placing crushed ice under it while the snowflakes are photographed.

3. *Warm air is pushed up by cold air.* In cold weather, when the house is heated, open a window slightly and, with a thermometer, measure the changes in temperature that occur in the room as the cold air enters. What had been a room of relatively equal

YOU CAN LEARN MORE ABOUT
The Scientist's Way

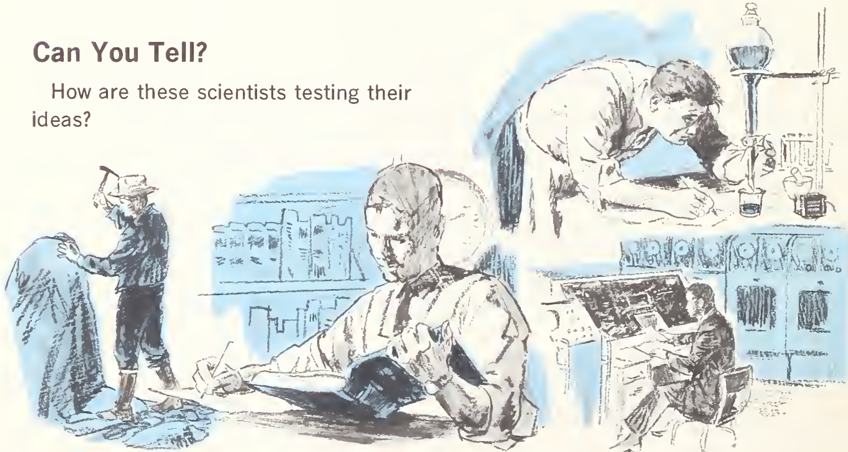
Testing Hypotheses

Make up a hypothesis to answer each of the questions below and then tell how you would test your hypotheses.

1. What organisms live in the soil?
2. How can snowflakes be photographed?
3. Is warm air pushed up by cold air?
4. Do younger and newer layers of rock rest on lower and older rocks?

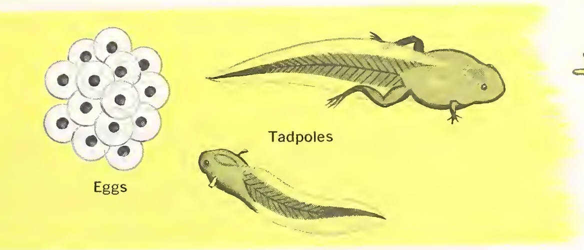
Can You Tell?

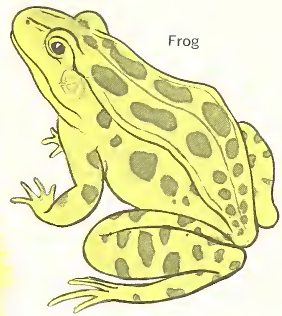
How are these scientists testing their ideas?



What Do You Think?

Look at the three pictures below. What do they have to do with the frog on the right? How can you test your ideas to see if you are right?





You Can Read

1. *It's Fun to Know Why,* by Julius Schwartz. Simple experiments help you uncover the secrets contained in coal, glass, soap, wool, and other materials.
2. *Here's How It Works,* by Duane Bradley and Eugene Lord. You will learn how many machines, tools, and scientific devices work.
3. *The Crazy Cantilever, and Other Science Experiments,* by Robert R. Kadesch. You can do over 40 experiments in physics by following the simple directions in this book.
4. *Science Puzzlers,* by Martin Gardner. A more advanced book than the others, but with it you will have much fun and learn much about science.

temperatures will now have cold temperatures near the floor while the upper levels remain warm.

4. *Younger layers of rock rest on older rocks, except where there has been folding or faulting.* This can be tested by observing the characteristics of rock formations in the country wherever the layers are exposed for any reason—for example, because of highway construction, water erosion, or construction projects. The age of rocks can be determined by radioactive dating.

Can You Tell?

The geologist is obtaining rock samples to check his ideas about the formation of the earth. The scientist in the library is checking the ideas of others to see whether they support or deny his own ideas. The scientist at the computer is testing his ideas by seeing whether his equations are accurate. The scientist in the laboratory is testing his ideas by running experiments that will prove or disprove them.

What Do You Think?

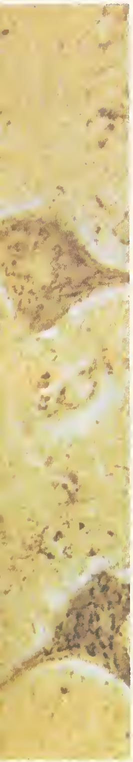
The pictures illustrate the development of a frog from an egg. This idea can be tested by obtaining frog's eggs and watching the developmental process.

KEY CONCEPTS

Key Concept 1. Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

Key Concept 3. To find order in the natural environment, the scientist seeks basic units that can be put together in an almost infinite variety of ways; the cell and the atom are examples of such units.

Key Concept 8. There is a relationship between structure and function; the structure of parts of living organisms determines the function of those parts.



2

Other concepts appear under "Learnings to Be Developed" in each lesson found in the Teaching Suggestions.

Cells, Tissues, Organisms

Discovering the Cell
Examining the Cell
From One Cell to Many Cells

CONCEPTS:

1. Hooke was the first to observe and describe "cells."
2. According to the cell theory, all living things are made of cells.
3. Microscopes have been used to extend man's vision.
4. Through studying cells, scientists are learning more and more about life.
5. Cells have structure.
6. Cells are classified according to their structure and function.
7. Groups of cells that work together are called tissues.
8. Groups of tissues that work together are called organs.
9. Organs that work together are called systems.
10. All the systems working together make up an organized living system, or organism.

PROCESSES:

- Observing—Pages 30, 31, 32.
- Experimenting—31, 32.
- Comparing—30, 31, 32.
- Inferring—31, 32, 33.
- Classifying—31, 37.
- Selecting (sources from recall) —24.
- Demonstrating—30, 34, 35, 39.
- Explaining—30, 31, 32, 33.

TEACHING SUGGESTIONS
(pp. 24–25)

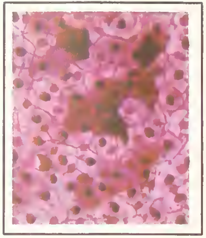
LESSON: How was the cell discovered?

Background: Until the development of the microscope it was impossible to see that there is a fundamental unit of structure present in all living things.

The first simple microscopes appeared in Holland in the late 1500's. They were not much more than hand lenses. The Dutch lens grinder Leeuwenhoek (1632–1723) made some excellent simple microscopes, which revealed animals and plants in a drop of rainwater.

Robert Hooke, an Englishman, invented a compound microscope consisting of sets of lenses, which vastly improved the quality and magnification of microscopes. He examined many things with it, including minerals, textiles, and small plants and animals. He also examined cork, which is part of the outer bark of the cork oak. His published observations laid the basis for the cell theory.

Although Hooke is credited with naming the cell, he was actually describing the dead parts of cells, the cell walls.



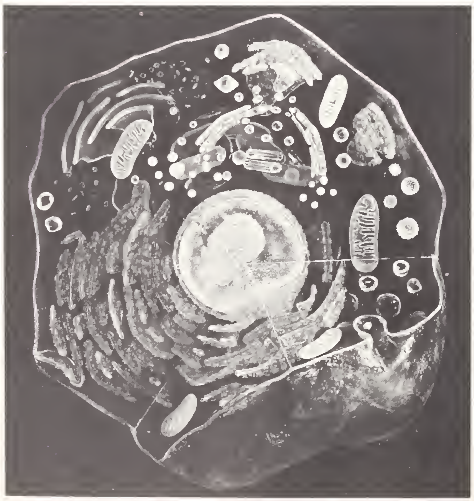
Discoveries in science are made because scientists build on the work done by other scientists. The ideas of one man may start other men thinking. One discovery may lead to many others. In this unit you will learn about some exciting discoveries that were made following the invention of the microscope.

Discovering the Cell

Why do you grow? Why do you stop growing? Why is each of you different from every other living person? How do life and growth begin? Man has always been curious about life. Scientists now know that all living things are made up of **cells.** To study life, you must study the cell.

A very simple animal such as the ameba is made up of only one cell. Within this one cell, all the life activities are carried on—getting food, using food, getting rid of wastes, and producing more cells like itself.

Most animals, unlike the ameba, are made up of many cells of different



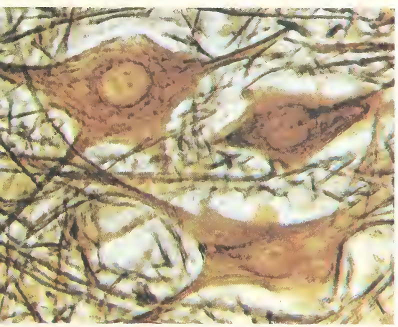
If a model of the cell is available, show it to the class.

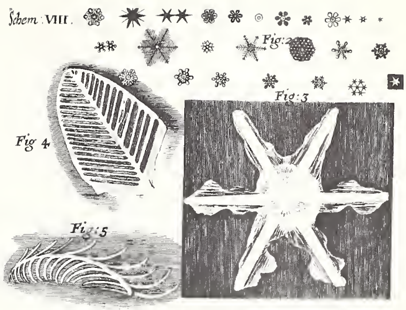
This is a model of a cell. It shows how a cell might look if it were magnified many hundreds of times. You can see that there are many parts within the cell.

kinds. Each different kind of cell carries on a specialized job. You are a many-celled animal. Right now, the cells in your brain are carrying on the special job of storing away information about what you are reading.

Cells are very small. They must be magnified many times under the lenses of a microscope to be seen and studied. Until four hundred years ago, scientists did not have the instruments to study cells or any other very small objects. The invention of the microscope in the 1600's made it possible to see very small things. Invisible worlds that men did not even know existed became visible under the lenses of the microscope. It was now possible to explore these worlds.

These cells are found in the human brain. What special job do you think such cells have?





Robert Hooke observed many objects with his microscope and made drawings of what he saw. What do his drawings above show?

Robert Hooke Looks at Cork Cells

In the 1660's the curator of experiments of the Royal Society of London was Robert Hooke. Hooke improved the microscope so he could explore the unknown world of very small things. Keeping careful notes and making detailed drawings, he studied many things under his microscope. Among these things were a bee, a flea, and a thin slice of cork. The most important of his observations were made about the slice of cork. Here are some of Hooke's comments in his own words about what he saw.

"I took a good clear piece of cork and with a pen-knife sharpened as keen as a razor, I cut a piece of it off, and thereby left the surface of it exceedingly

Learnings to Be Developed: Robert Hooke was the first to observe and describe "cells."

Developing the Lesson: Discuss the cell theory from the historical point of view, showing that knowledge in science is an accumulation of the discoveries of many men and their interpretations. Science is a continuing search for a refinement of our existing knowledge and for new knowledge.

- *What are the instruments of science?*

They are the extensions of man's senses. The microscope extends the range of man's vision, down to the wavelength of light. Beyond this he uses the phase microscope and the electron microscope. Knowledge of plant and animal structure before the 1600's was limited to observations with the naked eye.

- *In what ways do you think Robert Hooke's concept of a cell differed from the present ideas concerning it?*

Cork is the bark of a species of tree. It is dead material. Hooke was actually describing the cellulose cell walls. His ideas did not include the cell as a unit of *function*. It was merely a unit of *structure*.

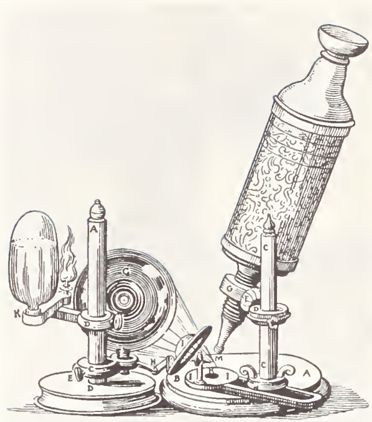
TEACHING SUGGESTIONS
(pp. 26–27)

● **LESSON:** What is the cell theory?

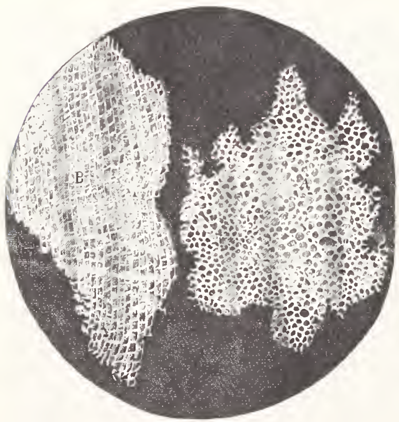
Background: The cell has been accepted as the unit of life for only a little more than 100 years. Because it is impossible for the unaided eye to detect cells within tissues, development of the cell theory inevitably awaited development of the art of microscopy.

One of the earliest microscopists, Robert Hooke, gave the cell its name (Latin *cella,* a chamber or storeroom) in 1665. But the realization that cells of all organisms are similar came only gradually, and it was not until 1838–1839 that Matthias Schleiden and Theodor Schwann propounded the cell theory as such. Although few of their ideas were original, and some were wrong, they succeeded in establishing the theory in definite form, and it proved to be a strongly unifying influence in the fields of botany, zoology, and physiology.

Schwann stressed the importance not only of "plastic phenomena," or morphology of the cell, but also of "physiological phenomena," or chemical changes, which he designated as "metabolism." This was a century after René Descartes had introduced the concept that



Robert Hooke used the microscope shown above to look at a thin slice of cork. The drawing he made is shown below. What do you see?



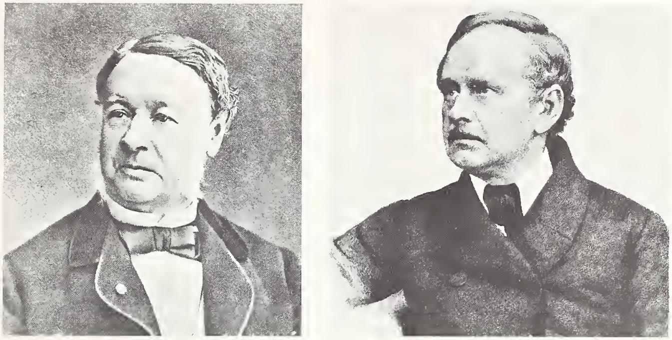
Hooke saw only the cell walls of cork, not living cells.

smooth, then examining it very diligently with a microscope, me thought I could perceive it to appear a little porous. . . . I with the same sharp pen-knife, cut off . . . an exceeding thin piece of it." (He then placed it under his microscope.) "I could exceedingly plainly perceive it to be all perforated and porous, much like a Honey-comb, but that the pores of it were not regular. . . . These pores or cells were not very deep, but consisted of a great many little boxes. . . . Nor is this kind of texture peculiar to cork only: for upon examination with my microscope I have found that the pith of an Elder or almost any other tree, the inner pulp of several . . . vegetables . . . have much such a kind of Schematisme as I have lately shown that of cork."

In his description, Hooke described the holes in the cork as "cells." He used the word *cells* because the holes made him think of the cells of a honeycomb. This was the first time *cell* was used in print to mean a part of a plant.

The Cell Theory

Later, other scientists studied living things with a microscope. They saw what Hooke had seen and more. In 1824, Henri Dutrochet (doo-troh-SHAY), a French surgeon who retired in order to have more time to study and



Theodor Schwann and Matthias Schleiden developed the cell theory over one hundred years ago. How did this theory advance man's understanding of living things?

experiment, stated that all living things are made of cells. After many observations, he said also that growth results from an increase in the size of existing cells and from the addition of new, smaller cells which increase in size.

Before other scientists would accept Dutrochet's findings, they needed more detailed and complete evidence. It came fifteen years later when, in 1838 and 1839, Schleiden and Schwann published their findings. Schleiden discovered that plants are built of cells and grow from single cells. Schwann found the same to be true of animals. He was the first to use the phrase *cell theory*.

The cell theory says that all living things are made of one or more cells or of cells and their products. As a result of the work of many scientists, the cell theory now includes more information: All cells come from cells, and the activities of all living things are possible because of the activities in cells.

Scientists today have a much more powerful instrument with which to study the cell. This instrument is called an electron microscope. Look on page 28 at the photograph showing blood cells as seen under the type of microscope your school has. It is called a light microscope, because you need a source of light to see with it. Now look at the photograph of the same cell as seen under an electron microscope. The light microscope made worlds visible which were not dreamed of before. The electron microscope lets scientists explore

an organism is a machine using energy. In spite of this early recognition of the metabolic aspects of the cell, cytology was predominantly morphological in the 19th century; by the end of that century almost every structure in the fixed and stained cell that could be seen with the light microscope had been described, but little was done to relate the form to the function of cells.

Only recently have physical and chemical methods begun to penetrate the ultrastructure of cells and correlate it with metabolism. As finer and finer structures of the cell are revealed and their chemistry is elucidated, there is developing a concept that F. O. Schmitt has called "the morphology of molecular complexes."

Learnings to Be Developed: According to the cell theory, all living things are made up of cells.

Developing the Lesson: Continue the historical approach, interweaving the above information.

TEACHING SUGGESTIONS
(pp. 28–29)

● **LESSON:** What can we see with the microscope?

Learnings to Be Developed: Microscopes have been used to extend man's vision.

Developing the Lesson:

Explain the correct manner in which to handle a microscope. Point out the parts of the compound microscope: the *optical,* which include two sets of lenses; the *mechanical,* which include the arm, the coarse and fine adjustments, the body tube, the stage and base, and the low- and high-power objectives; and the *reflecting,* which include the flat and concave sides of the mirror. The diaphragm is below the stage.

Demonstration of correct focusing procedure is of utmost importance.

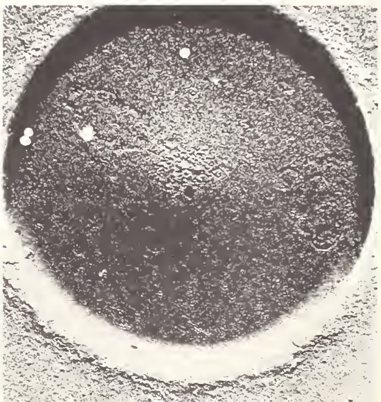
Distribute bits of newsprint for practice in microscopic examination. Tell the children to mount the newsprint in the center of the slide. Cover it with a cover slip. Focus carefully (use low power if the microscope is compound).

Compare the appearance of a letter as viewed under the microscope and as seen with the naked eye. Move the slide to the left.

these microscopic worlds more fully.

The future promises to be exciting. In your lifetime, scientists expect to learn more about the basic secrets of life. With this knowledge, perhaps they can prevent some of the diseases people now get. They may even be able to extend your life span by controlling aging. The possibilities are as limitless as man's imagination.

At the top are blood cells magnified by a light microscope. At the bottom you see *one* red blood cell magnified 18,400 times by an electron microscope. Compare these magnifications with those of cork cells on page 26.



PATHFINDERS IN SCIENCE

Severo Ochoa

(1905–) Spain

Arthur Kornberg

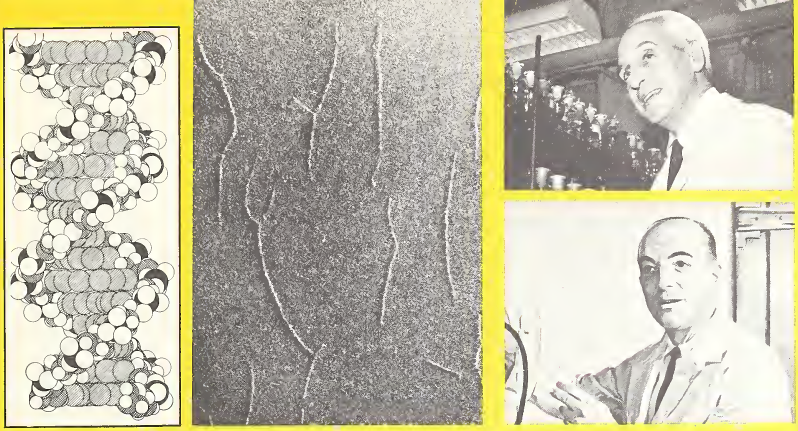
(1918–) United States

In 1959 a teacher and his former student shared the Nobel Prize in medicine and physiology. Severo Ochoa (oh-CHOH-uh), a professor at New York University, was the teacher, and Arthur Kornberg was his student.

What did the two men do? Dr. Ochoa made ribonucleic acid (RNA) (ry-boh-noo-KLEE-ik) in his laboratory, and Dr. Kornberg made deoxyribonucleic acid (DNA) (dee-AHK-see-ry-boh-noo-KLEE-ik). To understand the importance of their work, you first must know the story of the nucleic acids.

One of life's greatest mysteries has always been how a tiny fertilized human egg starting as one cell can grow into a human body with billions of different cells, many organs and functions, and the ability to reproduce. Scientists have traced the secret to the nucleic acids RNA and DNA, which are found in every cell.

Proteins are the building blocks of life. Nucleic acids (RNA and DNA) are the blueprint that determines the structure of the building blocks. RNA is found in the



On the left is a model of DNA. Its shape is that of a double *helix*. In the center are DNA molecules magnified 100,000 times by an electron microscope. At the top right is Dr. Severo Ochoa, and at the bottom right is Dr. Arthur Kornberg.

Use pipe cleaners to illustrate a double helix structure.

cytoplasm, around the nucleus of the cell, and DNA is found in the nucleus of the cell. Scientists believe that the nucleic acids are the key to the way in which living things are born with, or *inherit*, certain characteristics. RNA and DNA determine that baby whales look like whales and baby ants look like ants. RNA and DNA determine, among other characteristics, the color of the eyes and hair of every human baby.

Both DNA and RNA are in the shape of long chains. The chains are made up of certain molecules, and are twined around each other like a spiral staircase, or *helix*. DNA reproduces itself in a way that is described like this: Two chains of DNA fit together as a hand fits into a glove. They come apart. The hand then acts as a mold for the formation of a new glove and the glove acts as a mold for a new hand. Thus there are two gloved hands where there was only one before.

Scientists believe that the nucleic acids control the making of proteins in each organism. DNA is the master mold for passing heredity patterns from generation to generation. RNA is the copy used in the actual manufacture of proteins.

Dr. Ochoa and Dr. Kornberg were the first scientists to make test-tube models of DNA and RNA, models that resemble the real nucleic acids both physically and chemically. Their work provided other scientists with the means of probing further into the secret of life.

- *How does the letter appear to be moving?*
- *Move the slide to the right. How does the letter appear to move?* (A microscope inverts an image. Up becomes down, and left becomes right.)

Have the children look at a hair under low and high power. Compare the appearances.

ADDITIONAL ACTIVITIES:

If a compound microscope is available, demonstrate the use of the high-power objective.

- *At which power is more detail seen?* (High power with a loss of clarity.)
- *Under which power do you see a larger part of the hair?* (Low power.)
- *Under which power is the amount of light reduced?* (High power.)
- *What can be done to increase the amount of light?* (Use concave mirror; open diaphragm wider; use substage lamp.)

Summarize the differences between low and high power. In general, high power magnifies more and shows a smaller area in greater detail. Unless you have a very expensive microscope, there will be a loss of definition as you increase magnification.

TEACHING SUGGESTIONS
(p. 30)

Background: This *Using What You Have Learned* section does not pose questions that require specific answers. If the children, alone or as a class, perform some of these activities, they will probably raise their own questions. Most of these questions will center around structure identification. It will not be necessary for you to be able to answer all questions. The raising of questions of this type is typical.

One of the most versatile instruments for class study of microscopic particles is the microprojector. There are many varieties available that allow large groups to view a complete microscope field, which is under the control of a teacher.

Using What You Have Learned

1. A magnifying glass is a lens. Because you hold it in your hand to use it, it is called a hand lens. Before microscopes could be built, lenses had to be made that would magnify many times more than your hand lens. High-powered lenses were first made about four hundred years ago. Some were used in making telescopes to observe the moon and planets. Some were used in making the first microscopes. A microscope has several lenses in it. Examine one to find out where they are located. Do you understand how a microscope works? Learn how to examine things under a microscope. Read *The Microscope and a Hidden World to Explore* by Irene S. Pyszkowski to find out how to use and care for a microscope.

2. Put bits of thread, hair, soil, and salt on microscope slides. Now look at them through a microscope. Compare their sizes under the microscope with their sizes under a hand lens.

3. Now look at strips of newspaper, aluminum foil, and cloth, a leaf, and the wing of a butterfly under your microscope. You should be able to see fibers in the paper and the cloth. Can you see the thin veins of the leaf? Why can you see the veins of the butterfly wing so clearly? How can you make the veins of a leaf easier to see under the microscope?

To see an object well under your microscope, light must pass through the thing you are looking at. The mirror at the bottom of your microscope reflects light from a window or electric bulb so light goes through the object you are observing.

4. Now repeat Robert Hooke's experiment. Ask an adult to use a single-edge razor blade to shave off a very thin layer from a piece of cork. Examine the cork layer with your microscope. You will see the little "boxes" or "cells" that Hooke saw.

Examining the Cell

You, a rosebush, a sparrow, an elephant, an ant, a snake, and a shark are made of cells. The cells that make up a rosebush are different from those that make up an ant. How do they differ? With the aid of a microscope, you can easily examine the kinds of cells that make up plants and animals.

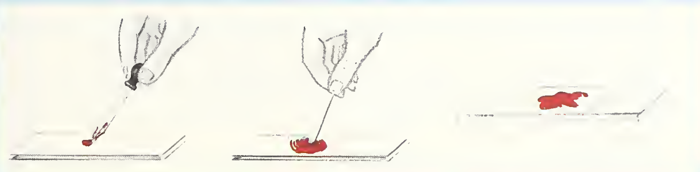
What Do Cheek Lining Cells Look Like?

What You Will Need

glass slide	iodine thinned with water	flat toothpicks
cover slip	(1 part iodine to 2 parts	medicine dropper
microscope	water)	

How You Can Find Out

1. Place a drop of iodine in the center of a clean slide.
2. Scrape the inside of your cheek with the flat part of a toothpick.
3. Roll the end of the toothpick in the drop of iodine.
4. Place a cover slip over the iodine.
5. Look at the slide under the low power of your microscope.



Questions to Think About

1. What do you see?
2. Why were you told to add iodine to the water?
3. If you have high power on your microscope, use it to look at the cells. What do you see now?

TEACHING SUGGESTIONS
(p. 31)

● **LESSON:** How does a cheek lining cell look under a microscope?

Learnings to Be Developed:

Microscopes have been used to extend man's vision.

Cells have structure.

Developing the Lesson: Provide each child with a flat toothpick. Tell him to scrape gently inside his cheek with the flat end of the toothpick. Put a drop of dilute iodine at the middle of the slide.

Place the scraping on the iodine solution. Cover with the cover slip. Examine the slide under the microscope. (Use low power.)

• *Describe the shape and appearance of the cheek cells.*

Have children locate nucleus, cell membrane, and cytoplasm. Have children make half-page drawing of what they see.

Background: The answers to the *Questions to Think About* are:

1. Refer to the microphotograph on page 33, upper right.

2. Iodine will stain parts of the cell more than other parts.

3. Less of the cell is visible, but the parts become larger.

TEACHING SUGGESTIONS
(pp. 32–35)

LESSON: How do live onionskin cells look under a microscope?

Learnings to Be Developed:

Cells have structure.

Structure is related to function.

Developing the Lesson: Cut an onion into small squares. Float these in a small bowl of water to keep the tissue fresh until ready to be used. Use forceps or your fingernails to peel off thin, transparent layers of tissue from the inside (concave) surface of the square. With a medicine dropper put a drop of water on the middle of the slide. Place the onionskin on the drop of water. Flatten the tissue. Cover with a cover slip. Ask pupils to examine the tissue.

Put a drop of dilute iodine at the edge of the cover slip, allowing it to seep into the tissue. Ask children to reexamine slide.

- *What effect does the iodine have on the tissue?* (Provides contrast by staining some parts.)

Have the children describe the shape and appearance of the cells. Point out that a cell has three dimensions (length, breadth, and thickness). This can be seen by focusing carefully up and down with the fine adjustment.

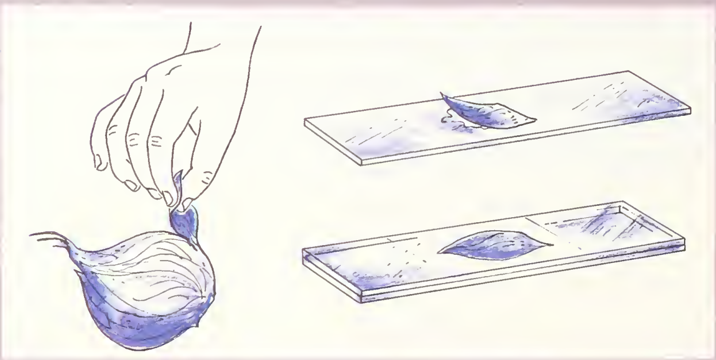
What Do Onionskin Cells Look Like?

What You Will Need

glass slide
cover slip
some iodine thinned with water
(1 part iodine to 2 parts water)
microscope
medicine dropper
onion

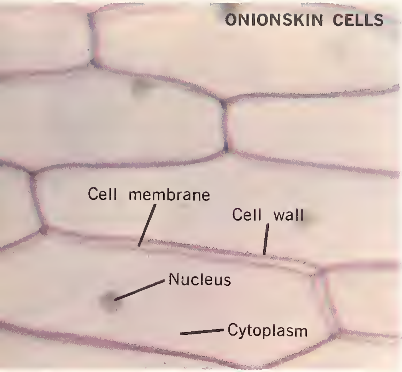
How You Can Find Out

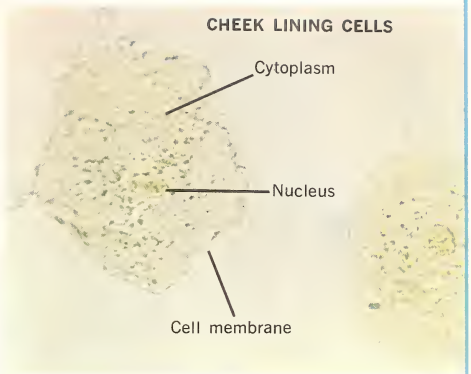
1. Place a drop of iodine in the center of a clean slide with the medicine dropper.
2. Gently pull the skin off a piece of onion.
3. Put the onionskin in the drop of iodine.
4. Place a cover slip over the drop of iodine.
5. Look at the onionskin first under the low power of your microscope, then under the high power.



Questions to Think About

1. What do you see?
2. Why were you told to add iodine to the water?
3. What do you see better under high power than you saw under low power?





Look at the cells from a plant and the cells from an animal. What do you see that is the same? What is different? Can you identify plant cells and animal cells without knowing the names of the living things from which they came?

Now that you have compared cells from an onionskin with cells from the lining of the mouth, can you tell the ways in which these cells are alike? Did you see a round object inside each cell? It is called the **nucleus.** The nucleus directs the growth and reproduction of the cell. In the space around the nucleus of the cell is the **cytoplasm** (SY-tuh-plaz'm).

Can you tell the ways in which these cells are different? Around the edge of the onionskin cell is a thick, firm wall called the **cell wall.** A plant's cell wall is made of **cellulose** (SEL-yoo-lohss), which is not living. Now look again at what looks like a thin line around the cheek cell. This part of the cheek cell is the **cell membrane** (MEM-brayn). The cell membrane is living material.

Animal cells do not have cell walls of nonliving cellulose. Animal cells have only a cell membrane. But plant cells have both a cell membrane *and* a cell wall.

The nucleus, cytoplasm, and cell membrane of a cell are alive. When Robert Hooke looked at the thin slice of cork under his microscope, he saw the cell walls of cork cells, but he did not see the nucleus or cytoplasm. Do you know why he saw only the walls of the cork cells?

The children should be able to find the round nucleus (stained yellow-orange), which usually is near the center. They should also be able to identify the cell wall. Have them note that this gives the cell a different shape from the cheek cell; the edges are straighter. The cytoplasm consists of granular material near the cell wall and nucleus. The large spaces are vacuoles, which store cell sap.

Review the functions of cell parts: The nucleus controls heredity and most cell functions. The cell wall provides protection and support. In the cytoplasm cell energy is released and stored. The vacuole stores cell sap. The cell membrane permits gases and liquids to enter and leave the cell.

Follow-Up: How can we show that a membrane exists inside onion cell? Place a few drops of weak salt water (2%) on a slide containing onion tissue. Tell the children to watch what happens under the microscope. They should see shrinkage of the cell contents. The membrane shrinks away from the cell wall as water leaves the cell. If purple onion is used, this shows up very sharply. The purple color becomes more intense inside the vacuoles, indicating loss of water by the cell.

○ **ADDITIONAL ACTIVITIES:**

Have the class observe a green plant cell under the microscope.

Obtain a healthy sprig of *Elodea* from a fish supply store. Using a pair of forceps, remove leaflets and place each in a drop of water on a clean slide. Cover with a cover slip. Tell the children to observe and describe the appearance of the leaf cells as viewed under low power. Have them turn the fine adjustments slightly up and down to see the layers of cells.

Have the children focus under high power and note the small, oval-shaped, green-colored object distributed in parts of the cell.

- *What are they?* (Chloroplasts, which contain chlorophyll.)
- *What is their importance?* (They are needed for photosynthesis.)
- *Do they move?* (They can be made to move if the slide is warmed for a minute or two in the palm of the hand. They are carried by movement of the cytoplasm, called *cyclosis,* or streaming.)
- *Does the cell have a nucleus?* (Find the nucleus, a denser small round body near the middle of the cell.)

The Shape of Cells

When you look at pictures of cells, such as those of onionskin and cheek cells, you may think that cells are flat like a sheet of paper. You may even get this idea when you look at cells through a microscope. But cells are not flat. What shape are cells?

Have you ever looked down from a tall building at the people below? If you have, you know that you do not see them as they really are. They look like flat objects moving along. Keep this in mind when you look at cells. Cells are not thin, flat objects. They are three-dimensional. They have length, width, and height like the cell shown in the picture below.

The model in the picture below shows a three-dimensional view of a cell.

What Cells Are Made Of

Scientists called biochemists have studied what cells are made of. They have found that a large part of a cell is water. However, in the water are minerals made up of elements such as sodium, calcium, and potassium. There are sugars, fats, and proteins in the water, too. These are made up of carbon, hydrogen, oxygen, nitrogen, and other chemical elements.

Some of the materials in living cells are dissolved in the water. To see what happens to materials when they are dissolved in water, mix a spoonful of sugar in water. What happens to the sugar crystals? Why can't you see them when the sugar is dissolved in water? When sugar crystals are mixed with water, they break up into smaller bits called sugar **molecules** (MOL-uh-kyoolz). Sugar molecules are too small to see. The sugar seems to disappear when its molecules are scattered throughout the water. You cannot even see them with a microscope.

Some of the materials in living cells, such as fats and proteins, are not dissolved in water. They mix with the water, but they do not dissolve.

If you put a spoonful of cooking oil in a jar of water, you will see that it does not mix with the water. However,

Shake the jar with oil and water. What happens? What happens when you stop shaking it?

if you shake the jar hard for some time, some of the oil will break up into smaller bits. When you stop shaking it, they will collect again at the top of the water. If you had a way of breaking the oil into very small bits, they would stay scattered throughout the water. This is what happens when milk is homogenized. The butterfat in the cream is broken up into small bits that mix evenly throughout the water in the milk. They do not collect and come to the top of the milk as cream. If you put a drop of homogenized milk on a microscope slide, you can observe the small bits of fat with a microscope. They are not dissolved. Many of the materials in living cells are scattered in the same way as the butterfat in homogenized milk.

You could mix together all the contents of a cell in just the right amounts, but the mixture would not produce the living material of a cell. Scientists have been successful in making some parts of the living cell. Some day they may be able to make all of it. However, today only a cell can produce more living material. Or, to put it another way, only a cell can produce another cell.

Using What You Have Learned

Use a toothpick to examine the white of an egg. Note how thick and sticky it is. Most of the egg white is protein and water. The protein is not dissolved in the water. In this way, egg white is something like the contents of a cell.

Tiny strands of cytoplasm may be found surrounding the nucleus and going toward the cell wall. The large spaces are vacuoles.

Have the children make a full page drawing of a green plant cell and label all parts seen.

Review what has been learned to date and have the children make a list of the cells they have seen (cheek cell, colorless plant cell, and green plant cell). For each type of cell they should indicate presence or absence of the following parts: cell wall, cell membrane, nucleus, cytoplasm, vacuole.

What does the electron microscope reveal about the structure of the cell?

Show the picture of the red blood cells on page 28, and point out that this cell looks quite different from anything they have seen under the ordinary microscope. Explain that the ordinary compound microscope magnifies 150X under low power and about 440X under high power. (Magnification is obtained by multiplying the powers of the ocular and objective lenses: 10 ocular X 15 objective = 150; 10 ocular X 44 objective = 440.) Even the most powerful light microscope magnifies less than 2,000X.

TEACHING SUGGESTIONS
(p. 36)

● **LESSON:** What advantages do many-celled animals have over one-celled animals?

Learnings to Be Developed: Cells are classified according to their structure and function.

Developing the Lesson: Have the children look at the pictures of one-celled animals (ameba and paramecia) on this page.

- *What functions are performed by each cell?* (Protection, securing food, movement, reproduction, etc.)

Show a picture of a colonial hydroid (for example, a sponge, which may be found in a zoology textbook or in Buchsbaum's *Animals without Backbones*, by University of Chicago Press). Although hydroids are very simple animals, some members of the colony are used for protection, others for obtaining food, still others for reproduction.

- *Why is this a better arrangement than having one cell do everything?* (Specialization permits greater efficiency; each cell concentrates on a particular activity.)

Ameba

Paramecia

Diatoms

Each of these living things is only one cell. Which are plants? Which are animals?

From One Cell to Many Cells

All living things begin life as a single cell. But you know that you are made up of more than one cell. So are roses and elephants and most other plants and animals we have named. In fact, each of these living things is made up of many billions of cells. How, then, did they all develop from single cells?

Each cell divided into two cells, the two cells into four cells, the four cells into eight cells, the eight cells into sixteen cells, and so on, until many billions of cells were produced. It is believed that an adult weighing 160 pounds has about 60,000,000,000,000 cells. That's sixty thousand billion cells —and all from one cell!

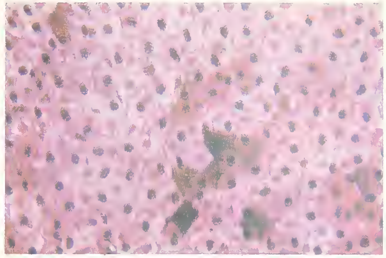
Similar Cells Make Up Tissues

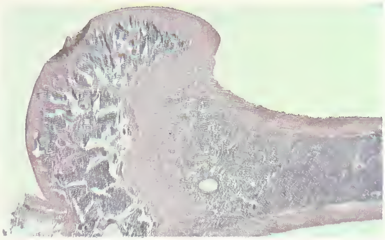
Some plants and animals, like diatoms and amebas, are made of only one cell. But most plants and animals have many cells. You are made of many cells. Some cells make up your bones, some make up your muscles, and some cells make up your skin. All bone cells look very much alike; so do all muscle cells.

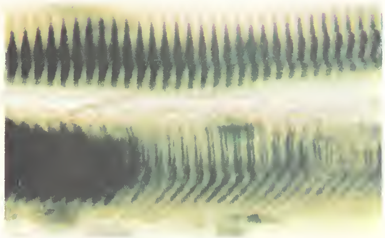
All the cells that look alike are useful in the same way. All skin cells protect, all bone cells support, and all muscle cells move. Groups of similar cells are called **tissues** (TISH-ooz). Billions of cells make up your body, but all of these may be divided into five kinds of cells that make up your tissues.

TISSUES OF THE HUMAN BODY

1. **Covering tissue.** This tissue covers the surfaces inside and outside your body. Skin cells make up the skin tissue that covers the outside of your body.





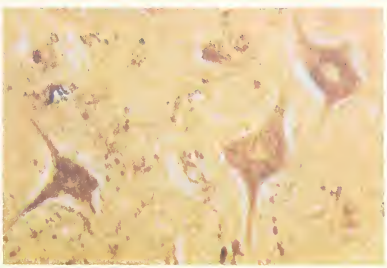


2. **Connective and supporting tissue.** This tissue supports your body and holds your cells and other tissues together. The cells of connective tissue spread among other cells and bind them together. Bone cells build bone and teeth.

3. **Muscle tissue.** Your muscles are formed from muscle cells. You have three kinds of muscles: heart muscle, muscles of the food tube and blood vessels, and muscles that are attached to your bones, which enable you to move.

4. **Nerve tissue.** Your brain, nerves, and sense organs are made of nerve tissue. Nerve tissue carries messages from one part of the body to another.

5. **Blood tissue.** Blood is a tissue. Two kinds of cells in blood are red cells and white cells. Red cells carry food and oxygen. White cells fight disease.



TEACHING SUGGESTIONS
(p. 37)

● **LESSON:** How do the various tissues look under a microscope?

Learnings to Be Developed: Tissues are classified according to their structure and function.

Developing the Lesson: Prepare slides of fresh tissues from a freshly dissected frog, as described in *A Sourcebook for the Biological Sciences* (Harcourt, Brace, 1958), pp. 131 and 281–283, or obtain prepared stained slides from one of the biological supply houses listed in the Teachers' Guide.

Have the children look at muscle and blood cells under the microscope and describe what they see. Point out the numerous tiny, oval, red corpuscles in the frog's blood. These contain nuclei, in contrast to human red blood cells, which lose their nuclei early in their development. White cells may be seen if a blood smear is made.

Note: An excellent teaching aid is produced by National Teaching Aids, Inc., 120 Fulton Avenue, Garden City Park, New York. Request a sample of their microviewers and slides of one of the following: "Cells of Your Body," #10, "Pond Life," #12, or "Cells of Plants," #11.

TEACHING SUGGESTIONS
(pp. 38–39)

LESSON: How do the body organs of a frog compare with those of a human?

Learnings to Be Developed:

Cells are organized into tissues that perform similar functions.

Tissues are organized into organs.

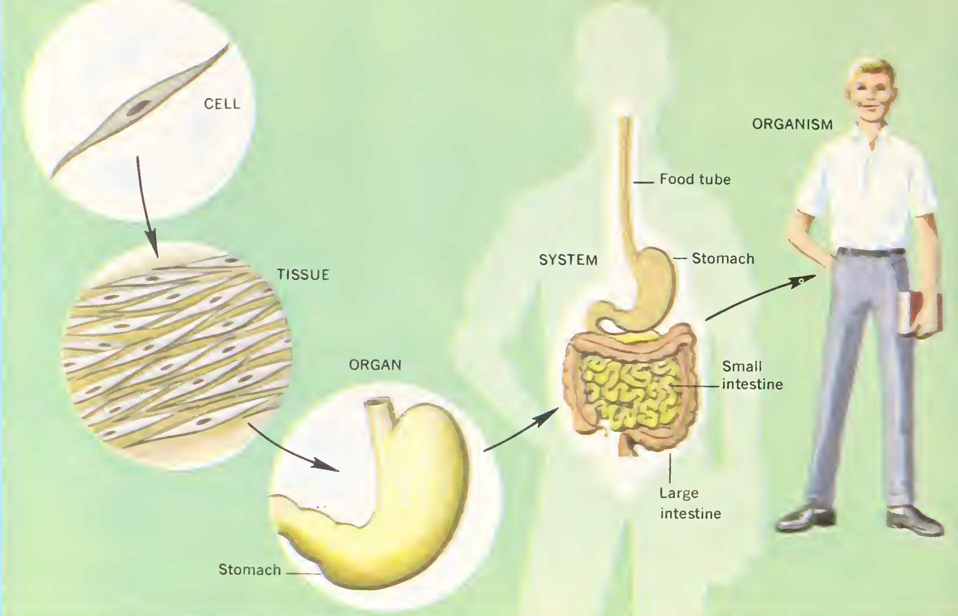
Organs that work together make up systems.

Systems that work together form organized living systems, or organisms.

Developing the Lesson: Show the correct way to dissect a frog. Locate and describe the digestive organs, including mouth, tongue, gullet, stomach, liver, gall bladder, pancreas, and intestines.

Background: The following material will help you explain activity 2 in *Using What You Have Learned:*

When a jar of water in which soil has been mixed is shaken, the heavier particles will settle to the bottom, while the lighter particles will rise to the top of the water. The water remains cloudy because of the smallness of some of the particles; it may take a very long time for all of them to settle.



How does this chart show the structure of an organism?

Tissues Make Up Organs

Tissues are groups of cells that work together. But one kind of tissue cannot work alone. Tissues are grouped together to form **organs.** Each organ is made of different kinds of tissues. Your heart is an organ. Your heart is made mostly of muscle cells held together by connective tissue. But you know that the heart also has blood tissue. And it has nerve tissue. Covering tissue lines the inside and covers the outside of the heart. All the tissues that make up the heart work together to pump the blood.

An organ is a group of tissues that work together. Cells make up tissues and tissues make up organs. You have many organs: eyes, ears, heart, brain, kidneys, lungs, intestines. What others can you name?

You have a brain, a spinal cord, nerves, and several sense organs (eyes, ears, nose, etc.). All these organs work together. With these sense organs you can see, hear, smell, taste, and feel. All these organs together make up a **system.** It is your *nervous* system. You have a nose, a windpipe, and lungs. These organs make up your breathing, or *respiratory*, system. You have a food tube which includes the stomach, small intestine, and large intestine. All these organs are a part of your *digestive* system. Another system in your body is the *circulatory* system. See if you can name the parts of your circulatory system.

Organized Living Systems

All the systems in your body work together. All animals and plants are **organized living systems.** Cells are organized into tissues, tissues are organized into organs, organs are organized into systems, and systems are organized into living systems called **organisms** (OR-gun-iz'mz).

You, a rosebush, a sparrow, an elephant, an ant, a snake, and a shark are all organisms. Even the one-celled ameba is an organism. Though it does not have tissues and organs, it is still an organized living system. All one-celled animals and plants are organisms. Every living plant and animal is an organism.

Using What You Have Learned

1. Build a three-dimensional model of a cell. Label the cell membrane, nucleus, and cytoplasm.

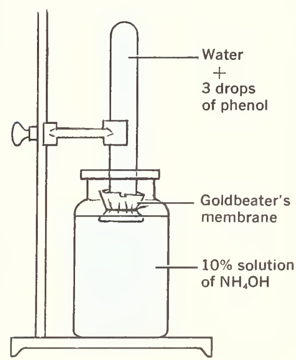
2. Place a cup of soil in a quart jar of water. Shake the jar until the soil is mixed with the water. Set the jar on a table and observe what happens. Which particles settle first? Why does the water remain cloudy even after most of the material has settled? In what way is this water mixture like the one in the cytoplasm of a cell? Examine a drop of the cloudy soil water with a microscope. Explain what you see.

In time, the only particles that will remain suspended are those whose size is extremely small and whose density is about equal to that of water. Milk is an example of a mixture of this sort, called a *collodial suspension.* The water mixture resembles the cytoplasm in a cell in that various particles of matter are suspended in the cytoplasm. (A distinction should be made between substances that are suspended in the liquid and those dissolved in the liquid.)

ADDITIONAL ACTIVITIES:

The purpose of this activity is to show how a gas behaves in passing through a membrane.

Materials and equipment you will need are: 1. Test tube, 2. Collection bottle, 3. Solution of NH_4OH 4. Cigarette cellophane or goldbeater's membrane, 5. Indicator (phenol), 6. Water.



TEACHING SUGGESTIONS
(pp. 40–41)

Background: These two pages constitute a review of the concepts and terminology introduced in this unit.

What You Have Learned: This is a summary of the entire unit, with new words in boldface type.

Checklist of Science Words: Remind the pupils that there is a *Dictionary of Science Words* on pages 358–364. They should consult this dictionary whenever they are unsure of the precise meaning of a word.

WHAT YOU KNOW ABOUT

Cells, Tissues, Organisms

What You Have Learned

All plants and animals are made up of **cells.** Robert Hooke developed one of the first microscopes through which to see cells.

Two German scientists, Theodor Schwann and Matthias Schleiden, developed the **cell theory,** which states that all living things are made of cells and develop from single cells.

Every cell has a **nucleus,** which directs the growth and reproduction of the cell. The **cytoplasm** is the material around the nucleus of the cell. Around the cytoplasm is a **cell membrane.** A plant cell also has a **cell wall** around its cell membrane.

Much of a cell is water containing minerals, made of elements such as sodium and calcium. There are also **molecules** of sugar, fat, and protein in the water of the cell.

Groups of cells that work together are called **tissues.** There are five kinds of tissue: covering tissue, connecting and supporting tissue, muscle tissue, nerve tissue, and blood tissue. Groups of tissues that work together are called **organs.** The organs that work together are called **systems.** All the systems working together make up an **organized living system,** or **organism.**

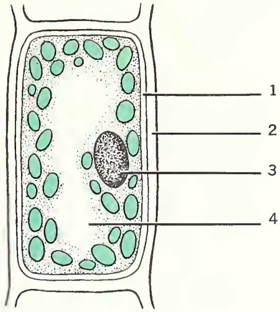
Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

cell membrane	cytoplasm	organism
cell theory	nucleus	system
cell wall	organ	tissue

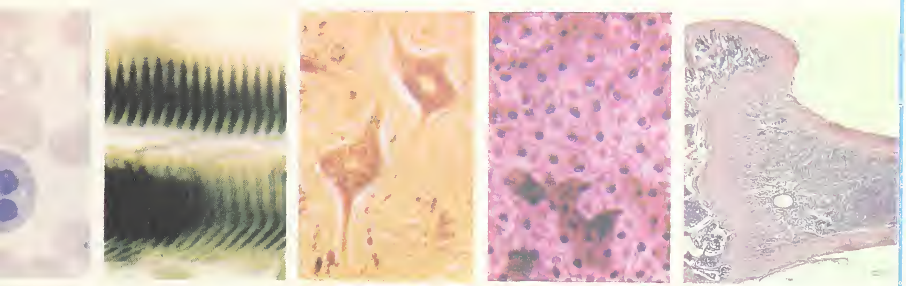
Name the Parts

Look at the drawing of the cell. On a page in your notebook, write the name of each part that is numbered. Is this cell a plant cell or an animal cell? How can you tell?



Which Tissue?

1. This tissue covers the surfaces inside and outside your body.
2. Your sense organs are made of this tissue.
3. This tissue causes movement.
4. These tissues support your body.
5. This tissue transports foods and wastes into and out of cells.



Name the Parts:

1. Cell membrane
2. Cell wall
3. Nucleus
4. Cytoplasm

The cell is from a plant, because it has a cell wall, a large vacuole, and green chloroplasts.

Which Tissue?

1. Covering tissue: second from the right.
2. Nerve tissue: center.
3. Muscle tissue: second from the left.
4. Bone tissue: far right.
5. Blood tissue: far left.

TEACHING SUGGESTIONS
(pp. 42–43)

Background: These pages reinforce the concepts presented in the unit by suggesting activities that extend the pupil's ability to apply the learnings derived from the unit.

Unscramble the Letters:

1. Cell theory
2. Nucleus
3. Cytoplasm
4. Organ
5. Cellulose
6. Tissue
7. Organism
8. System

YOU CAN LEARN MORE ABOUT

Cells, Tissues, Organisms

Unscramble the Letters

1. All living things are made of one or more cells or of cells and their products.
2. The part of the cell that directs growth and reproduction.
3. The material around the nucleus of the cell.
4. Tissues that work together.
5. The nonliving material of a plant cell wall.
6. Groups of cells that are useful in the same way.
7. Any living thing.
8. Organs that work together.

1. LELC RETOHY
2. LUNECSU
3. OCTMASLYP
4. GNOAR
5. SOLCEELUL
6. IUTSSE
7. MSIAGONR
8. YSTMSE

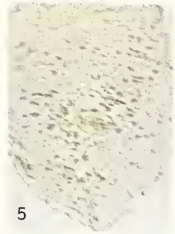
Making Models

Use clay to make a display showing how cells form tissues, tissues form organs, organs form systems, and systems make up an organism.

What Is It?

Look at the pictures below and on the right. Copy the number of each picture in your notebook and next to it write whether the picture is of a cell, a tissue, an organ, a system, or an organism.


4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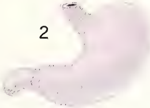
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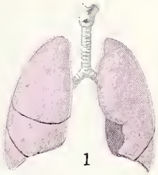
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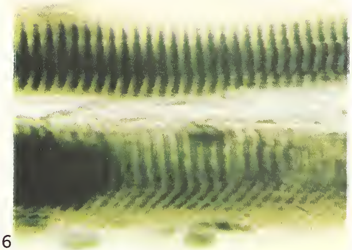
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You Can Read

1. *Experiments with a Microscope,* by Nelson F. Beeler and Franklyn M. Branley. Many projects using a microscope are described.
2. *What Is a Cell,* by Fred M. King and George Otto. Tells about the structure of cells and their activities.
3. *Golden Book of Biology,* by Rose Wyler and Gerald Ames. Covers cell structure, heredity, and other topics.
4. *The Science of Life,* by Lois and Louis Darling. An advanced book that covers the life processes.

What Is It?

1. The trachea and lungs: a system.
2. The stomach: an organ.
3. A squirrel: an organism.
4. The heart: an organ.
5. A cheek cell: a cell.
6. Muscle cells: a tissue.

You Can Read: Additional pupil readings include:

Adventure Book of Biology, by Otto P. Burgdof (Golden Press, Inc., 1962). Gives a good description of the human body.

Your Wonderful Body, by Robert J. R. Follett (Follett Publishing Co., 1961). A well-illustrated beginning science book about the human body and how it works.

You and Your Cells, by Leo Schneider (Harcourt, Brace & World, 1964).

Inside You and Me, by Eloise Turner and Carroll Fenton (John Day Co., 1961). The fundamentals of human anatomy.

KEY CONCEPTS

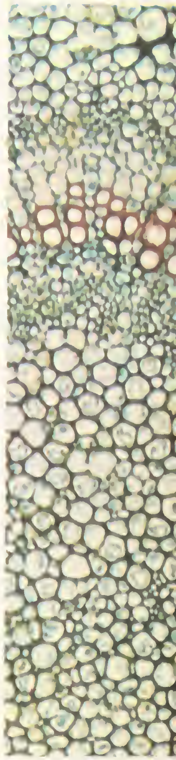
Key Concept 1. Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

Key Concept 3. To find order in the natural environment, the scientist seeks basic units that can be put together in an almost infinite variety of ways; the cell and the atom are examples of such units.

Key Concept 8. There is a relationship between structure and function; the structure of parts of living organisms determines the function of those parts.

CONCEPTS:

1. Many living things, including humans, begin as a fertilized egg.
2. After fertilization, cells divide, grow, and change to become the different parts of a complex organism.
3. The structural and behavioral development of a living thing from a fertilized egg is an orderly, predictable process.
4. Hormones regulate growth.



3

Other concepts appear under 'Learnings to Be Developed' in each lesson found in the Teaching Suggestions.

Growth and Development

How Animals Grow
How Plants Grow
Human Growth

PROCESSES:

- Observing—Pages 47, 51, 54, 55, 58, 60, 71.
- Experimenting—60, 61.
- Comparing—51, 54, 60, 61, 66, 68, 69.
- Inferring—49, 50, 54, 60, 61.
- Measuring—51, 60, 61.
- Classifying—49.
- Selecting (sources from recall) —48, 59.
- Communicating—69, 71.
- Demonstrating—47, 50, 53, 66, 69, 71.
- Explaining—48, 54, 55.

TEACHING SUGGESTIONS
(pp. 46–47)

LESSON: How does a new organism begin?

Background: The essence of life is change. The essence of nonliving is inertia. From the first moment of life, an organism begins a series of changes that ultimately result in a series of characteristics that we recognize as adult.

Developmental events are seen most dramatically in the growth patterns of higher animals. The fertilized egg undergoes a very orderly series of changes to become an embryo which develops into the young animal and then goes on to become an adult. At maturity the animal releases eggs or sperm, which can originate yet another cycle of development.

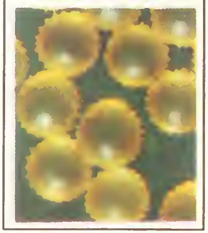
Such development is not restricted to the higher animals. It occurs in the lower ones as well. It also is found in the plant kingdom.

Fertilized eggs of all animals undergo the same pattern of development—cleavage, or splitting; differentiation and growth.

Learnings to Be Developed:

Many living things, including humans, begin as fertilized eggs.

An embryo is a developing individual.



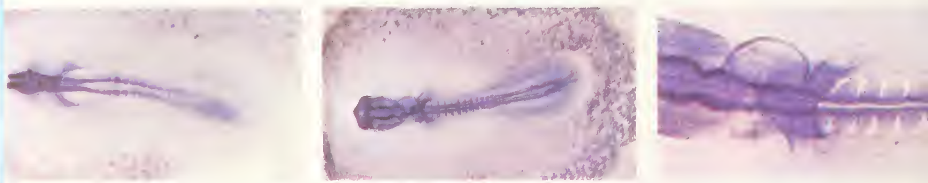
You, a rosebush, a sparrow, an elephant, an ant, a snake, and a shark grew and developed from single fertilized egg cells. All animals with backbones, and most others, begin as single egg cells. Flowering plants also begin as single egg cells. In this unit you will learn how living things grow and develop.

How Animals Grow

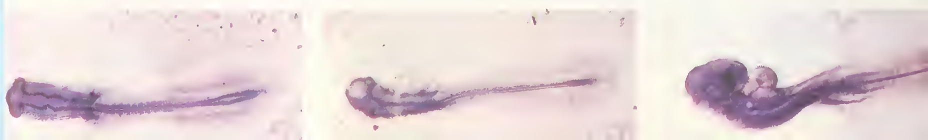
The series of pictures below shows the way one animal grows from a single fertilized egg cell. Many animals develop in the same way. However, the amount of time it takes for them to develop fully differs. Follow the pictures in order. What do you see happening as the cells divide?

These photographs show the first 16 to 23 hours in the life of a chick.

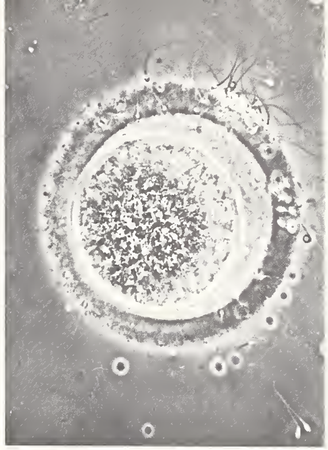
After 24 hours the brain is seen forming. On the right is a view of the heart.



After 36 hours the chick begins to twist. Note that the eye lens is formed.



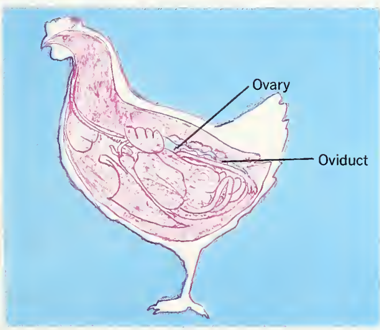
You have seen that a chick begins its life as one cell. The egg cell of a chicken is large compared with the egg cells of many other animals. For this reason it is easy to examine the egg of a chicken. Crack open a chicken egg. Look at the yellow part, or **yolk,** of the egg. Do you see a white spot on the surface? This small spot becomes the chick **embryo** (EM-bree-oh). This part of the egg contains the nucleus of the egg cell. The egg cell will not develop into a chick embryo unless it is **fertilized** (FER-t'l-yzd).



The sperm cells have tails that enable them to swim. Note size relationships.

How the Egg Cell Is Fertilized

The egg cell is produced in the **ovary** (OH-ver-ee) of the hen, as you can see in the diagram. If your mother buys a whole hen with its insides intact you may be able to find many egg cells in it. The egg cells are attached to the ovary by very thin stalks. The ovary is on the left side of the hen. The cells attached to the ovary are very small. All you can see are the yellow yolks. Look for them next time your mother buys a hen. Be sure to look before she cooks it. As the egg cell passes through a tube in the chicken, called the **oviduct** (OH-vih-dukt), the white is added.



But before the egg can develop into a chicken, it must be fertilized. Fertilization occurs when special cells from the rooster called **sperm cells** reach the egg cells. The picture above shows the size of a sperm cell compared to the size

Developing the Lesson: To introduce this unit, enlist the experiences of the class. For example, ask:

- *How many of you have pets at home?*
- *How many raise plants or flowers as a hobby?*

If any of the pets were born at home, or brought in as "babies," elicit any observations that may have been made concerning their growth and development, and list them on the blackboard.

Discuss the inadequacy—from the standpoint of communicating important sequential information accurately—of the various observations.

Point out the value of written records of observations of various stages of development. Relationships among organisms are discovered when similarities of development are noted by comparison of records. Developmental defects can be studied, and possibly prevented by close and systematic study of records of development.

Emphasize that, while accidents have played occasional roles in the advancement of knowledge and understanding, the vast majority of our information has come from patient and systematic observation and the keeping of accurate records.

TEACHING SUGGESTIONS
(pp. 48–50)

LESSON: How does a hen's egg develop into a chicken?

Background: Here we touch on some of the larger problems of biology.

The egg starts as a single microscopic cell; by replication and growth it produces an adult containing millions of cells. A number of questions are sure to arise when we discuss this phenomenon. How is growth initiated? What raw materials are required to build new protoplasm? What chemical reactions lead to the formation of new body structures, new cells, new tissues, and a new individual?

Another significant facet of growth is that all the parts of the organism increase in a regulated manner. That is, if a cell doubles its size, the size of the nucleus, cytoplasmic inclusions, cell membrane, etc., all increase in proportion to one another. When a chicken grows from the embryo to a hen, its organs increase harmoniously. The length of the wing bears a fixed relation to the body size, and within certain limits so do other portions of the body. There must therefore be a regulatory mechanism in cells and tissues that governs such relationships. What is this mechanism?

Here is a picture of rooster sperm as seen under a microscope.

of an egg cell. Notice how very small the sperm cell is. Can you give a reason for the large size of the egg cell?

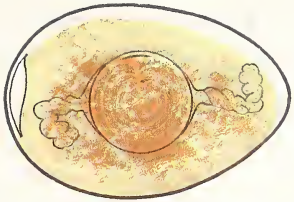
The largest part of a sperm cell, called the *head*, is the nucleus. The rest of the sperm cell is made up of a long slender tail that enables it to move to the egg cell. When a sperm cell reaches the nucleus of an egg cell, the nucleus of the sperm cell joins with the nucleus of the egg cell. The egg cell is then fertilized. When do you think this takes place — before or after the shell is formed around the egg? Give a reason for your answer.

Incubating Eggs

What happens after a fertilized egg is laid by a hen? Nothing much will happen unless the egg is kept at a temperature of about 103° F. At this temperature, the fertilized egg will develop into a chick. Hens cover the eggs with their bodies to keep the eggs at this temperature. The eggs may also be kept in special containers, called **incubators** (ING-kyoo-bay-terz), in which the temperature can be controlled.

It takes twenty-one days for a chick to develop from a single fertilized egg cell. This time period is called the **incubation period.** During the incubation period, many things take place inside the shell. At first the single cell divides many times. The new cells form a ball on one side of the yolk. The yolk itself does not divide. With what does the yolk provide the egg?

These girls belong to a science club whose project is to study the development of the chick.



Notice how the egg is held in place within the shell. Where is the embryo located?

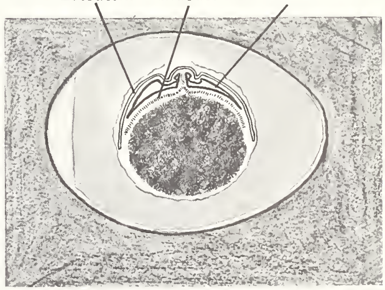
Biologists who study animal development have carefully noted what happens after an egg cell is fertilized. They have made many observations with microscopes. They have kept records, including photographs, of each stage of development. From these records, accurate and detailed descriptions of what happens have been prepared.

Some day you may study the science of the early development of living things. It is called **embryology** (em-bree-OL-uh-jee). Can you tell why this science is called embryology?

The Development of a Chick

Soon after the ball of cells forms inside the egg cell, it looks pushed in on one side. You can see in the diagram on the right that when this happens, three layers of cells are formed. Embryologists have given each of these layers a name. The name tells where the layer of cells is located. The **ectoderm** (EK-tuh-derm) is the outside layer. The **endoderm** (EN-duh-derm) is the inside layer. The middle layer is called the **mesoderm** (MESS-uh-derm).

The cells making up each of these three layers divide, grow, and change to become different parts of the chicken's body. The outer skin, feathers, brain, and nervous system are formed from cells in the ectoderm. The lining of the digestive tubes and breathing tubes is formed from cells in the endoderm. Endoderm cells also form the glands of the body. Cells from the



mesoderm produce the lower skin layer of the chick, the organs of the circulatory and excretory systems, and the muscles, bones, and cartilage.

Most of the answers will be for future scientists to supply. Today we are only on the trail of the complete answers.

Learnings to Be Developed: After fertilization, cells divide, grow, and change to become the different parts of the complex organism.

Developing the Lesson: Set up committees for several relatively long-range projects. Have each committee establish a regular routine of record keeping.

One committee can construct an incubator as directed on page 53. Among its other duties will be to record the temperatures obtained with light bulbs of different sizes (see step **f**, p. 54).

A second committee can incubate the eggs. This committee will need to locate and bring in the fertilized eggs for the experiment. They will have to organize individuals to be responsible for all duties required, such as temperature regulation, humidity regulation, the turning over of the eggs at regular intervals, the removal of the eggs at proper intervals, and their examination. To determine who should examine the eggs, a "dexterity" contest can be held in the class. You can begin with the nearly complete empty shells of hard boiled eggs, for

example, and have children attempt to cut a "window" in them. Work up to fresh eggs, so that when the observations on the incubating eggs begin, several "experts" will have been developed who will be charged with the delicate job of opening the eggs. (Be prepared for failure of embryos to develop, and examine all possible reasons. This will provide an opportunity to appreciate how critical are the various environmental factors.)

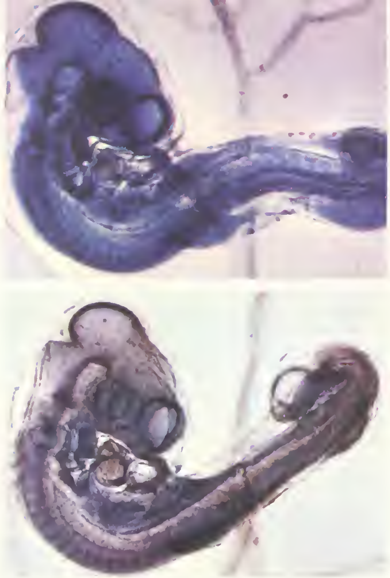
A committee can be organized to be responsible for the operation of a fish "hatchery," using fish eggs purchased locally.

A committee can be set up to establish a frog "hatchery." Very young tadpoles can be purchased and their development can be followed by the whole class while the other projects are going on.

○**ADDITIONAL ACTIVITIES:**

Embryos embedded in plastic can be purchased from various biological supply houses.

The National Film Board of Canada has a very appropriate color film entitled *Embryonic Development—The Chick.* A few terms are used which are probably above the vocabulary level of the fifth grade, but the photography and animation are excellent.



After 3 days (top picture) the tail and limb buds can be clearly seen. Eyes and ears can be seen, as well as regions of the brain. After 4 days the circulatory and nervous systems are also well along in their development.

If you have an incubator in your school, you can incubate chicken eggs and observe their development. Be sure to use fertile eggs. You can get fertile eggs from a chicken hatchery. Can you tell why eggs sold in stores usually are not fertile? If you do not have an incubator, you can get incubated eggs from a chicken hatchery. These will hatch shortly into chickens.

The photographs on page 46 show chick embryos at different stages of development. After a fertile egg has been incubated for 48 hours (two days), you can see the embryo's heart beating. You can also see how blood vessels cover the yolk. The yolk provides food for the embryo. The blood picks up food from the yolk and carries it to all parts of the embryo. The photographs on the left show developing parts of the chick embryo. See on this page and on page 46 how the embryo grows and develops from 16 to 96 hours.

If you have an incubating egg, you can observe the growth of a chick embryo yourself. It is possible to cut both the shell and the outer membrane away from the flatter end of the egg. The inner membrane must be painted with melted vaseline so that you can see through it and so that the growing embryo inside is protected. Take the

egg out of the incubator for a short time each day to observe the changing embryo.

Perhaps the most exciting development during the incubation period is the movement of the embryo inside the shell. The chick does not lie quietly before it hatches. Its movement, or behavior, starts before birth. This is true of many animals other than the chick. Kittens and puppies are active inside the mother before they are born. So are human beings.

How Behavior Develops

Embryologists, who have studied embryos of many different animals, have arrived at some ideas about how behavior develops. Look for some of these things as you observe the growing chick.

One idea is that development begins with the head and proceeds toward the tail. You will see in your chick embryo that the head looks like a head before the tail looks like much of anything. You will also see the first movements at the head end—a lifting and lowering of the developing head. Can you find evidence of a head-to-tail direction of development after birth? Look at some very young babies. How does the size of the head compare with the total length of the baby? How does the length of the legs compare with the baby's total length?

Another idea you may note as you watch the growing chick is that movement creates movement. One movement sets off another. The heartbeat is visible after the second day. It looks like a powerful beat for the size of the

How does this picture show evidence of the head-to-tail direction of development?

TEACHING SUGGESTIONS
(pp. 51–52)

● **LESSON:** How does behavior develop in a chicken embryo?

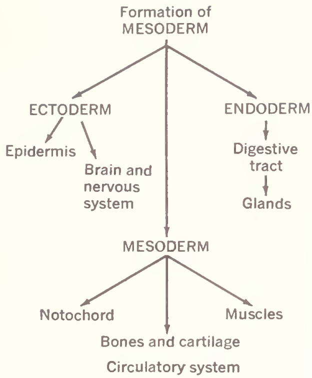
Background: Basically, an egg contains a single cell with the potential to grow into a reasonable facsimile of the parent. Accompanying this cell is a quantity of food in the form of yellow yolk granules. The size of the yolk is determined largely by the number of days that the embryo must grow before it is vigorous enough to get nourishment outside the egg. Another ingredient necessary for development is water. This is largely supplied by the "white" of the egg, which is also a protein food. The shell keeps the contents from spreading out and prevents excessive water loss. Eggs laid in water do not need a shell for this purpose.

The beginning embryo is noticed on the flat side of a yolk as a tiny speck, which develops into a streak similar to, but not the same color as, the first pictures of an embryo on page 46. Thereafter development occurs as the series of photographs indicates.

Learnings to Be Developed:

Development begins with the head and proceeds toward the tail.

Movement creates movement: one movement sets off another.



Developing the Lesson: If at all possible, do not neglect the experience of having your pupils grow embryos in an incubator.

Proceed by having a log of all anticipated activities on the part of the embryos. Be prepared to log unexpected results as well. Look for and record:

1. Heartbeat (pulsating) after second day
2. Bobbing of head
3. Growth of head and neck
4. Twisting
5. Opening and closing of beak
6. Appearance of limbs

Allow the children to describe the various observations in their own language. Allow descriptions that would be valid if you did not know otherwise. Permit as much freedom of expression in describing the observations as possible.

embryo. The throbbing of the heartbeat stimulates the head end and starts the rhythmic bobbing we have described.

Behavior and Environment

A fascinating thing is the way in which behavior changes as the environment changes. As the chick grows, the head gets bigger and heavier. The neck gets longer, but it stays slender. The head-bobbing then changes to a sideways motion. Another early movement is the twisting of the rest of the body. When the embryo gets too big for such activity within the shell, the movement gradually becomes a jerking one.

Perhaps the most important idea is that all of the movements the chick can make at birth have a long history in the egg. Newborn chicks can peck, but they have been practicing pecking movements almost from the beginning of life. Preparation for pecking started with the opening and closing of the beak at six days of embryonic life. By the seventh day, the embryo begins to thrust its beak forward, as if pecking. Wing and leg movements start before birth. Wing-buds and leg-buds move forward, backward, and sideways during the first ten days in the shell.

How did the newborn chicks peck their way out of their shells?

By the twenty-first day, the chick is fully formed and ready to hatch. Its muscles and nervous system have developed enough to enable it to peck a hole in the shell, stretch its body, break open the shell, and tumble out. A few hours later, the little chick's feathers are dry, and it can walk. The chick can get its own food and does not have to be fed by its mother, as do some other animals.

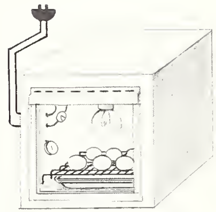
The various stages in the development of a chick from a fertilized egg cell are the same for all chickens. They are the same for all birds. In all cases, one stage of development follows the other in an orderly pattern. Scientists now believe that the nucleus of the fertilized egg cell has in it the "blueprint" for this orderly pattern of development.

There is an egg "tooth" of horny texture on the tip of the beak of many unhatched birds. It may sometimes be seen still attached to the tip of the beak of young chicks which have just hatched.

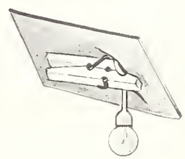
Using What You Have Learned

Your class can make its own incubator to observe the growth and development of chicken embryos:

a. You will need two cardboard cartons: one about 10 by 10 by 15 inches and the other about 12 by 12 by 17 inches or larger. You will also need a socket, a bulb, lamp cord, asbestos paper 10 by 10 inches, aluminum foil, a wall thermometer, and a thermostatic switch, which you can get at a hardware store. Someone can probably bring an aluminum cake pan about 7 by 9 inches and wire mesh about 11 by 13 inches from home. The mesh must be large enough to fit the floor of the small box with enough overlap to fold under to make a platform. This platform will hold the eggs over the cake pan.

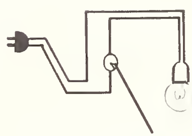


b. Cut one end off the small box. Cut a large window in the side of the large box to fit against the open end of the smaller box.



c. Suspend a light bulb from a hole in the top of the smaller box. Do this with a clothespin, as in the diagram. Put a piece of asbestos paper above the light. Have your teacher connect the thermostat, as shown in the diagram.

d. Next fit a pane of glass over the window opening. Make sure you tape all the edges for safety. Make a hinge for the window by using a double thickness of 2-inch adhesive tape. Staple the hinge to the box. Bend the wire mesh to fit above the cake pan. Put water in the cake pan.



e. Attach the thermometer and thermostat to the inside of the smaller box. Line the box with aluminum foil to reflect the heat toward the eggs. Pack crumpled newspaper between the two boxes for insulation.

TEACHING SUGGESTIONS
(p. 53)

Background: Time could be profitably spent in organizing the methods of collecting, recording, and presenting experimental data, in line with the suggestions of Unit 1, particularly page 6. As a matter of fact, each committee should develop a hypothesis that will guide its work. For example, the first committee's hypothesis might be, "An insulated box can be constructed so that a light bulb can be used to maintain a temperature of 103° F.," or "Fifty watts of electricity are needed to maintain a temperature of 103° F. in a home-constructed insulated box."

A committee can set up research problems, such as, "Using a hand lens, when is the earliest detectable heartbeat of the embryo established?" or hypotheses, such as, "Plastic wrap is more effective than melted vaseline in preventing drying out of the exposed chick embryo."

TEACHING SUGGESTIONS
(pp. 54–57)

LESSON: How do new plants develop?

Background: While most of the higher plants reproduce by sexual means, that is, by the fertilization of an ovule by pollen, many plants propagate by vegetative means. The eyes of the Irish potato illustrate this type of reproduction. The strawberry plant sends out long extensions (stolons), which, when they touch the ground, develop new plants. The leaves of begonias and African violets have the ability to start new plants.

Certain plants, such as bananas, some grapes, and navel oranges, must reproduce vegetatively, since they form infertile seeds or no seeds at all.

Learnings to Be Developed: After fertilization, cells divide, grow, and change to become the different parts of a complex organism.

Developing the Lesson: Have the class examine lima beans in detail, as directed in the text. Soak lima beans overnight. Be sure to have at least enough beans so that each pupil has one.

First have the class examine seed externally. Point out the "scar" on one edge. This "scar" consists of

f. You will have to try different-sized light bulbs until you find one that keeps the box at about 103° F. To regulate the heat level, make three or four 1-inch holes plugged with corks. You may remove these or insert them to regulate the heat level.

g. You are now ready to put in a dozen fertilized eggs. At the end of three days, remove an egg and examine its contents. See pages 50-51 for how to do this. Do this every three days for twenty-one days. Take notes and draw pictures of what you see.

How Plants Grow

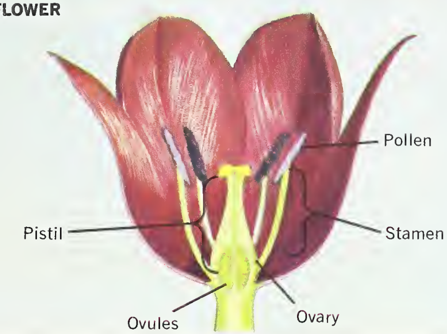
Biologists have studied animals that lay eggs, such as birds, frogs, and fish. They have studied mammals—that is, animals that bear live young—such as humans, cows, and pigs. Their research has led them to believe that all living things go through an orderly pattern of growth and development.

Identify the seed coat, the stored food, and the undeveloped plant. Check your answers.

You have studied how a chick develops. Now you will see how plants grow and develop. You will learn how plants develop by studying a seed.

What is a seed? Examine a lima bean seed that has been soaked in water overnight. Why should the lima bean be soaked in water? Seeds soak up a great deal of water, swell, and get soft. This makes them easier to examine. Cut open a seed. What covers the outside of the seed? What is underneath this covering? How is the underneath part different from the covering? What is it used for? What do you find between the two main halves of the seed?

PARTS OF THE FLOWER



When you have answered these questions, you will have located the three main parts of a seed: (1) the seed coat, (2) the stored food, and (3) the undeveloped plant. But how is a seed formed?

The Beginning of a Seed

The drawing above shows the parts of the flower that make the seed. Look at some flowers such as lilies, gladioluses, petunias, or tulips. Remove the petals and examine the parts shown on the drawing. The small, stalklike parts around the tubelike part in the center are called the **stamens** (STAY-munz). On top of each stamen is a powdery material, called **pollen.** With a toothpick, pick off some of this material. Examine it with a magnifying glass. If you have a microscope, you can see it much better. You will find, when you examine pollen, that pollen is made up of very small bits, called pollen grains.

Now examine the tubelike part in the center of the flower. This part is called the **pistil.** Touch the end of it with your pencil. It is sticky. Now follow the pistil down to where it is attached to the flower. Notice that the pistil is thicker there. This part is called the **ovary.** Carefully cut open the ovary with a sharp knife. You will see little white specks inside the ovary. These are called **ovules** (OH-vyoolz). Some of them will become the seeds after something else happens.

the *micropyle*, through which the pollen tube transferred the pollen into the ovule; and the *hilum*, the attachment to the ovary itself.

Have the pupils carefully remove the seed coat. (A seed coat can be paper thin, as is the brownish coat on the peanut, or it can be hairy, as is the cotton seed, whose seed coat produces the fibers that are spun into the material we call cotton.)

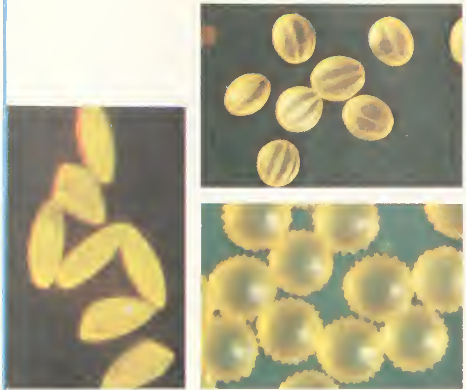
Tell the pupils to split the seed carefully by inserting a fingernail along the *outer* edge of the seed. In most instances, the two seed halves (*cotyledons*) will separate easily, and the embryo plant will remain attached to one of the halves. Magnifying glasses would be very helpful at this stage, so that the details of the embryo can be studied. It will consist of a *plumule* (2 folded, flattened, veined structures, which will become the first green leaves of the new bean plant), the *hypocotyl* (the thickened portion, which will become the stem), and the *radicle* (the very tip of the hypocotyl, which will become the new plant's root system).

○ **ADDITIONAL ACTIVITIES:**

Many experiments can be performed with plants that are difficult or impossible to do with ani-

mals. It must be emphasized that the phenomena associated with life and with the growth and development of organisms are the same in both plants and animals, and it is the general principles governing these phenomena that we wish to discover. For example, we may speculate on what it is that attracts the chicken sperm to the egg to achieve fertilization, but we can experiment with pollen grains to see what it is that causes them to achieve the same thing, the union of the hereditary material of one organism with the hereditary material of another organism so that a third organism similar to the first two can form.

- *What causes the pollen tube to germinate (begin to grow down the pistil)?* Let your pupils speculate.
- *Could it be a sugar solution that causes the pollen tube to grow?*
- *Why would that be a logical starting point for our investigation?* (Sugar as glucose is the most common substance made by green plants. Since pollen grains have no structures to respond to a physical stimulus, it is logical to think that there may be a chemical substance that stimulates the germination.)



Here you see pollen from three different plants —lily (top), bergamot (left), and squash (right).

Trace the path of the pollen grain after it lands on the sticky surface of the pistil.

You know that all living things are made up of cells. You also know that the nucleus is an important part of the cell. In order for most new living things to begin, the nucleus of one kind of cell must join with the nucleus of another kind of cell. In chickens, the sperm nucleus joins with the egg cell nucleus. In flowering plants, nuclei of cells produced by pollen grains must join with nuclei of the ovule cells for fertilization to take place. *Nuclei* means more than one nucleus.

When pollen grains land on the sticky part of the pistil, they begin to grow. They form long tubes which grow right down the center of the pistil until they reach the ovules in the ovary. When a pollen tube enters an ovule, the sperm nucleus joins the nucleus of an egg cell in the ovule. When this happens, the egg cell is fertilized. The fertilized egg now begins to divide. Cell division and growth continue until a small, undeveloped plant is formed. Because it is undeveloped, the plant is called an embryo plant.

The flowers of various kinds of plants look quite different. For example, the flower of a bean plant looks quite different from the flower of a tulip. But they both have stamens and pistils. Stamens and pistils are the seed-producing parts of the flower.

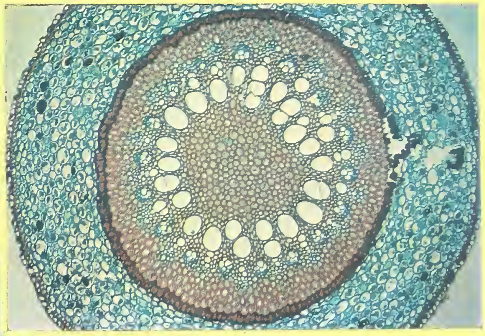
The Development of a Seed

When the egg cell is fertilized, it is one small cell. From this cell, a full-grown plant with roots, stems, and leaves develops. How does this remarkable development take place?

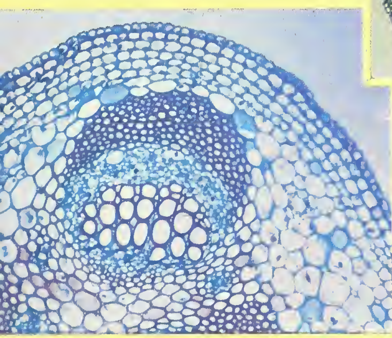
Look at the cells in the pictures below. In terms of their appearance, how many different kinds of cells can you find in the leaf? How many can you find in the stem? In the root? How are the cells arranged?

KINDS OF PLANT CELLS

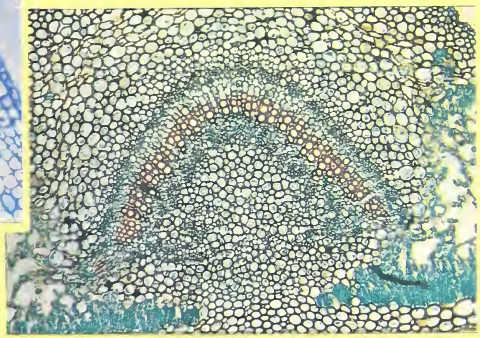
Root cells



Stem cells



Leaf cells



Experiment with the pupils.

First, make several sugar solutions —5%, 10%, and 20%. Then obtain pollen grains from different flowers. (If no flowers are in season, you can dust some into little envelopes at the local florist.) Cement a washer to a microscope slide, or place a ring of vaseline on a slide, or use a deep-well slide. Dust some pollen into the well, add the sugar solution almost to filling, cover it with a cover slip, and place the slide under a microscope, so arranged that it cannot be disturbed for several hours. Examine the slide every 15 minutes or so as the pollen tubes develop. This may take from 1 to 3 hours or even longer, depending on the type of pollen and the strength of the sugar solution. Germination of the pollen tube may continue over 1 hour, 50 hours (as in some tomatoes), or as long as 5 days (in cabbage.)

The conclusion of the experiment will be the organization of results —length of time to begin germination, percentage of sugar, percentage of grains germinating, etc.

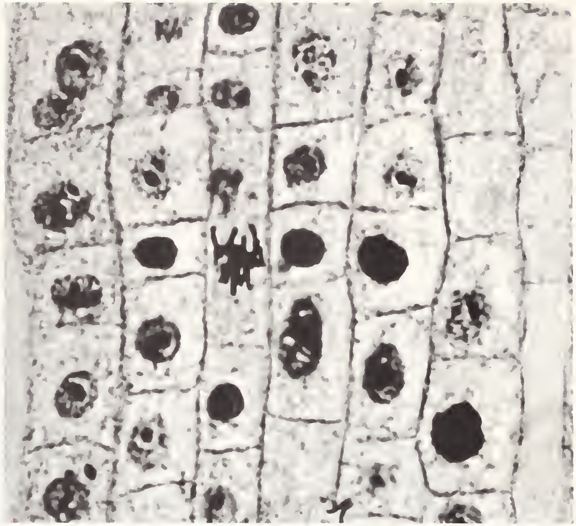
Another activity of great interest and instructive value is the making of clay or papier-mâchè cross-sectional models of the flower and of the lima bean. This activity requires intensive observation to achieve accuracy.

TEACHING SUGGESTIONS
(pp. 58–59)

LESSON: What activities take place in a germinating seed?

Background: A plant seed, consisting of the embryo plant and its food supply, is like a fertilized hen's egg in that it is entirely separated from the parent and is independent as far as its growth and development into an individual organism are concerned.

This independence is achieved by all seed-bearing plants in a remarkable process called *double fertilization*. The pollen grain contains two nuclei: a *tube nucleus,* which guides the development of the pollen tube from the stigma to the egg in the ovary, and a *generative nucleus,* which splits into two gametes, or sperms, as it moves down the developing tube. One of these sperm nuclei will unite with the egg nucleus. This fertilization will result in the embryo plant. The second sperm will unite with a second nucleus in the egg, called the *endosperm nucleus*. This second fertilization will result in the formation of the food supply for the embryo plant when it begins to grow (that is, when the seed germinates). The food supply will be needed until the first green leaves are formed, at which point the independent existence of the plant is established.



This is an onion root tip. Many cells are in the process of dividing. What do you see happening as they divide?

These different types of cells developed from one fertilized egg cell. When the fertilized egg divides, it forms two cells. The two cells divide to form four. The four divide to form eight cells. And so it goes, until the millions of cells making up the embryo plant within the seed have been formed. But something more takes place.

To get an idea of what happens, try this. Cut a piece of notebook paper into two parts. Now cut each of these parts into two. Continue cutting until you have sixteen parts. If you put all sixteen parts back together again, how large a piece of paper would they make? Suppose a fertilized egg cell produced, by cell division, sixteen cells. How big would each cell be? To produce the embryo plant in a seed, something more than cell division must take place. Actually, three things happen.

First, the new cells produced by cell division grow. They grow by taking in water and food materials from other cells in the plant. Many of the new cells become quite large. Second, some of the new cells change shape to form dif-

DEVELOPMENT OF A BEAN PLANT

ferent parts of the plant. Some change to become the cells of the roots. Some change to become cells of the stem. Others change to become the different kinds of cells in the leaves. And, finally, a third important thing happens. The cells become arranged into the pattern of an embryo plant.

Look at the diagram of an embryo bean plant. The plant in this diagram is larger than an actual embryo plant taken from a bean seed. But all embryo bean plants have this pattern. As you can see from the diagram, one part of the embryo develops into leaves and stem and another part develops into roots. This development, called **germination** (jer-muh-NAY-shun), takes place after the seed is planted. Some seeds, such as pea seeds, germinate soon after they are formed, even while they are in the pod. Have you ever found grapefruit or orange seeds that have germinated in the fruit? Some seeds, such as those of the Kentucky coffee bean, may be in the ground for many years before they germinate. Desert seeds germinate only after a rainfall.

Learnings to Be Developed: The structural and behavioral development of a living plant from a seed is an orderly, predictable process.

Developing the Lesson: Lima beans are probably the least expensive and the easiest seeds to study. Have all the children recall the lesson on how new plants arise, pages 54–56.

- *Does cell division alone account for seed germination or development?* (Obviously not, from a mathematical standpoint.)
- *What, then, accounts for change and for development into a new plant?* (The three items pinpointed on pages 58–59 should be emphasized: Each cell grows, divides, and grows; some cells change shape (differentiate) to form new tissues; and a pattern of organization, probably controlled chemically by hormones, emerges in the embryo plant.)

Many vendors of audio-visual equipment are producing single-concept films for multilevel use. These short (four- or five-minute) films are in loop form and have no sound.

TEACHING SUGGESTIONS
(pp. 60–61)

Background: Very often, the soaked beans will spoil or ferment before they begin to germinate. The smell can be so bad as to force an end to the experiment. This can be avoided by soaking the beans in water to which some clorox (or other liquid chlorine bleach) has been added. An experiment can be set up to determine which is the best percentage of clorox needed to prevent spoilage, and for how long the solution should be in contact with the seed. (As a motivational device, suggest that publication of these results could be of value to other science classes in the school or district.)

The answers to the *Questions to Think About* on page 60 are:

1. They are distended. They have fewer wrinkles.

2. The primary root begins to show itself by getting longer. The hypocotyl gets longer and epicotyl begins to show primary leaves.

3. They separate a bit and seem to move with the developing root system.

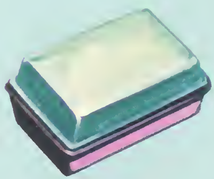
4. Times will vary, but the roots that are branching should appear shortly after the root leaves the seed coat.

How Does a Bean Seed Germinate?

What You Will Need

2 dishes or bowls | 12 paper towels | 12 lima-bean seeds

How You Can Find Out



1. Arrange three double layers of paper towels in the bottom of a deep dish or bowl.
2. Soak the paper towels with water by pouring water into the dish.
3. Lay twelve seeds on top of the wet paper towels.
4. Lay three double layers of paper towels over the seeds and dampen the top towels.
5. Cover the dish with another dish to reduce evaporation of water. We will call these dishes germination dishes.
6. Observe the seeds once or twice a day. As soon as they begin to grow, open one of them.
7. Carefully examine the plants each day. Keep a record of their appearance and size.
8. Compare the size of one of the plants—after roots, stem, and leaves have formed—with the size of a dry seed.

Questions to Think About

1. At the end of the first day, how can you tell that the seeds have taken up water?
2. What is the first sign that the embryo is growing? Which part pushes out of the seed first?
3. What happens to the two halves of the bean seed?
4. How long does it take for little roots to form along the side of the main root?
5. How long does it take for leaves to form?
6. How large is the largest bean?
7. Do all the seeds germinate? If not, what might have happened?
8. What will happen to the plants if they all remain in the dish without pruning?

EXPERIMENT

Do Different Kinds of Seeds Germinate at Different Times?

What You Will Need

10 radish seeds	10 bean seeds	10 corn seeds
10 pea seeds	2 germination dishes	16 paper towels

How You Can Find Out

1. Prepare your germination dish as in the activity on page 60.
2. Place the seeds in groups according to kind on the moist towels in your dish and cover them with moist towels. Cover the dish with another dish.
3. Observe daily and record how many seeds have germinated.

Questions to Think About

1. Which kind of seed germinates first? Which kind takes longest?
2. Why do different seeds have different germination times?

EXPERIMENT

How Does a Bean Plant Grow?

What You Will Need

pot or can of soil 10 bean seeds

How You Can Find Out

1. Plant the bean seeds about one inch apart and water daily.
2. Observe the pot daily and keep a record of your observations.
3. When the first plant begins to appear above the soil, carefully remove the entire plant from the soil and examine it.

Questions to Think About

1. Which part of the bean embryo comes through the soil first?
2. What has taken place beneath the soil when this happens?
3. How long does it take before the attached halves of the bean seed disappear?

5. The time again will vary with temperature and moisture.

6. Measure. Watch the shrivelling effect of the cotyledons as they give up their food supplies to the growing roots and leaves.

7. Probably not. Some may have been killed by storage heat; probably some were not viable to begin with.

8. Terminal growth should occur after the available space, moisture, and nutrients are exhausted.

Answers to *Questions to Think About* at top of page are:

1. The U.S. Dept. of Agriculture lists the following germination times for seeds: lima beans, 5–9 days at 78° F.; corn, 4–7 days at 78° F.; peas, 5–8 days at 68° F.; radishes, 4–6 days at 68° F.

2. The seed coat and state of dormancy of the stored seed are the usual factors.

Answers to *Questions to Think About* at bottom of page 61 are:

1. The loop formed by the root-stem system usually appears first above soil. If seed is deep in soil, the cotyledons appear first.

2. The beginning of the germination process described on page 59.

3. Variable.

TEACHING SUGGESTIONS
(pp. 62–63)

LESSON: Do all animals grow the same way?

Background: Many forms of animal life exhibit stages of growth that are quite distinct from their adult morphology. Insects exist in three or four forms, only one of which is recognizable as the adult insect. The frog undergoes a change from an aquatic, fishlike organism to the air-breathing adult. Some marine organisms (e.g., the oyster) exist in larval stages before reaching maturity.

Learnings to Be Developed:
Food is necessary for the growth of an organism.

The young of many animals look different from their parents.

Developing the Lesson: The frog is a member of the group of vertebrates called *amphibians.*

- *What is an amphibian?* (Its early life has a water environment and its later life a land environment.)
- *How does the tadpole breathe?* (Like all aquatic animals, it breathes through gills, which can be seen outside its body.)
- *How does the grown, or adult, frog breathe?* (Through lungs, as

Getting Food for Growth

A single fertilized egg cell requires certain materials to grow and develop into a many-celled complex organism, such as a tree, a chicken, or a human being. Food supplies these materials. You will recall that the chick embryo gets its food from the egg yolk. The embryo plant in a seed gets its food from materials stored in the seed. The human embryo gets its food from its mother's body.

Some insects and other animals have another way of getting food as they develop from a fertilized egg. The fertilized eggs of these other animals do not develop directly into little animals that look like the adult that laid the eggs. They first develop into an animal called a **larva** (LAHR-vuh) that looks like a worm.

The moth is an example of this type of animal. As you know, the eggs of a moth develop into caterpillars. The caterpillar is a larva. When a moth egg hatches into a larva, it is very small. But the larva immediately begins to eat leaves and other foods. During the

Common forms of pupae that can be obtained are Cecropia, Polyphemus, Promethea, and [illegible]

The orange-striped oak worm lays its eggs on oak leaves. When the eggs hatch, the caterpillars have a ready source of food. About a month later, the caterpillar spins a cocoon around itself. This is the pupa stage. What comes out of a cocoon?

The pupa is the stage in which the caterpillar spins a cocoon about itself.

When live eggs have been fertilized, they rotate within the layers of jelly so that all show the black area uppermost. When the cream-colored part is still uppermost, the eggs are dead or have not yet been fertilized.

The three stages of a frog are egg, tadpole, and adult. How does the tadpole get its food? Where does it live? How does the adult get food? Where does it live? What physical change marks the point at which the frog is considered an adult? About how old is the frog when this change occurs?

time it is a larva, it eats a great deal. Its body gets larger and larger, and soon it spins a case or cocoon around itself. It is then called a **pupa** (PYOO-puh). While the pupa is in the cocoon, great changes take place. Almost all the organs of the larva are changed. The new moth develops from small clumps of cells in the pupa. As these cells grow and develop, they use as food the materials that were a part of the larva's body.

You have probably seen tadpoles. A tadpole is the fishlike stage of a frog.

any terrestrial animal does. Also, some oxygen is taken in through its moist skin.)

- *How does the frog breathe under water?* (It *cannot* breathe under water. It is an air breather, because it has lungs.)
- *Does this mean that a frog can drown?* (Yes.)

Do this activity with the class. Have pupils collect some frogs (or purchase several from a local pet shop). Place them in glass containers half-full of water. (The containers should be tall enough so that the frogs cannot stand on the bottom and extend their heads above the surface of the water.) Note that frogs, unlike fish, must stay close to the surface, pushing their nostrils above the water periodically to breathe.

A good single-concept film entitled *Cecropia Moth Life History* could be shown here. The film is five minutes long. It can be purchased from The Ealing Corporation of Cambridge, Mass.

For other visual aids you might want to use the filmstrip series *Animals with Backbones* or *Animals without Backbones*. Both by Encyclopaedia Britannica Films.

TEACHING SUGGESTIONS
(pp. 64–65)

Background: In genetics, the characteristics that are transmitted from parent to offspring are contained in the chromosomes. The chromosomes are made up of smaller units called genes. The genes, in turn, consist of special chemical compounds called deoxyribonucleic acids, or DNA. These were discussed briefly in the background to the biographies of Ochoa and Kornberg on pages 28–29. Each gene is, in effect, a molecule of DNA.

Beadle's and Tatum's work on the mold *Neurospora crassa* was done before the importance of DNA in the inheritance of characteristics was discovered, and it led up to that discovery. It is interesting that *Neurospora crassa* can live and multiply on nutrients that can be obtained easily and controlled in the laboratory. Therefore, by closely regulating the kinds of substances fed to the mold, the ways in which it makes use of its nutrients and converts them into useful organic substances can be closely studied.

As with all living things, the form of the daughter cells produced by the mold depends on the makeup of the genes in the nucleus of the mother cells. By subjecting normal

A tadpole is very small at the time it hatches. But it grows as it finds food by swimming around in the water. Slowly, the tadpole's body changes into the body of a frog.

An oyster is another animal that has a larval stage of development. Within twenty-four hours after the oyster egg has been fertilized, it produces a larva. At first the larva is so small you need a microscope to see it. The larva feeds on microscopic plants as it swims about in the water. In fifteen days it has grown to about the size of the period at the end of this sentence. Then the larva attaches itself to a rock or an old oyster shell at the bottom of the water and continues to eat microscopic plants. It grows, forms a shell, and becomes a fair-sized oyster in about two years.

PATHFINDERS IN SCIENCE

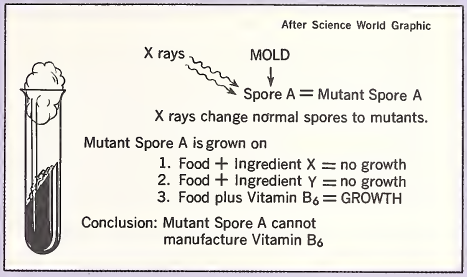
George W. Beadle

(1903–   ) United States

Like many other great scientists, Dr. George Beadle owes much to a teacher. "I thought I was going back to the farm," Dr. Beadle says, "but Miss Bess McDonald had a great ability to encourage her students to go ahead. She talked me into going to college."

Miss McDonald sparked a flame of enthusiasm for science in young George Beadle. She encouraged him to study at the University of Nebraska. There he became interested in *genetics*, the science of heredity. Genetics deals with such problems as why certain people are tall and others short and why different kinds of flowers are some colors and not others. Genetics deals with the problems of why living things are born, grow, and develop the way they do.

Dr. Beadle thought that one could come closer to finding answers in genetics by observing chemical changes one at a time in a simple organism rather than by observing numerous chemical changes in a complex plant or animal. He believed, for example, that tallness or shortness in a living organism might be the result of many chemical changes. He sought to study an organism



in which a change would be due to only one chemical reaction.

Dr. Beadle, working with Dr. Edward Tatum,/ found an almost perfect "guinea pig"—the red bread mold, which has the scientific name *Neurospora crassa*. One spore of *Neurospora* produces a great amount of mold all with the same characteristics. All that *Neurospora* needs to live is mineral salts, sugar, and biotin.

The two scientists X-rayed the mold. Their goal was to create offspring that differed from the normal mold in a simple chemical way. After exposing the spores to X rays, they gathered those spores formed by mating and placed them in a solution of mineral salts, sugar, and biotin. Some grew normally, others died, and a few began but did not continue to grow. Using a microscope, the two scientists carefully sorted out the spores that began to grow but for some reason did not continue. They sought the reason. After 209 experiments, they found that the reason these spores did not grow was that they were missing vitamin B_6. When these spores were mated with a normal strain, the need for vitamin B_6 was passed on to the offspring.

Beadle and Tatum had found that X rays changed the mold. This change made the mold unable to grow without outside help. The mold's need for vitamin B_6 was very much like a diabetic's need for the insulin that his body cannot produce.

The two scientists continued experimenting. Soon they had a great many molds that needed an extra nutrient or other kind of chemical. They had taken a big step forward in learning more about the growth and development of living things. Their success with *Neurospora* also provided *geneticists*, scientists who study genetics, with new techniques for using molds and other small organisms as tools to probe further into the growth and development of living things.

mold tissues to X rays, Beadle and Tatum upset the normal transmittal of characteristics to the daughter cells. As mentioned in the text, these daughter cells did not grow normally. This was because the daughter cells had lost the ability to form a particular organic compound that was necessary for full growth. Beadle and Tatum set themselves to discover what this missing substance was. By varying the nutrients fed the stunted mold, and by cross-breeding varieties of the mold, they could watch the effects of different chemicals on the cells and deduce what chemicals were required for growth.

As a result of their experiments, Beadle concluded that the genes in the nucleus of the mold cells had the function of forming enzymes that in turn built the necessary organic substances. When the genes did not perform their function properly, the necessary enzymes were not formed. The necessary organic compounds could not, therefore, be synthesized by the enzyme, and the growth of the mold was interrupted. Later, other scientists discovered that it was an upset in the structure of the DNA molecule that was ultimately responsible for the formation of the defective gene.

TEACHING SUGGESTIONS
(p. 66)

● **LESSON:** How do other animals, such as reptiles, develop?

Learnings to Be Developed:

Reptile animals develop from eggs that are laid on the land.

Some reptiles give birth to living young.

Developing the Lesson: Reptiles—turtles, snakes, lizards, alligators, and crocodiles—are the first true land animals. Let the class study the development of these animals.

- *Where do the eggs develop?*
- *How are the eggs protected from the environment?*

Reptiles lay their eggs on land, as birds do. The eggs may be buried in shallow soil or under leaves. Unlike the eggs of amphibian animals, the fertilized reptile egg is covered by a thin shell. This shell protects the growing embryo. The heat from the soil in which the eggs rest is needed for hatching.

- *How does the embryo get food?* Inside the eggshell is a yolk and egg white. Surrounding this liquid food supply is a membrane through which the embryo gets oxygen from the air.

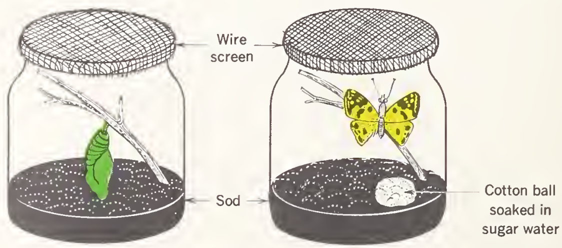
Using What You Have Learned

1. You can watch frogs' or toads' eggs develop into tadpoles. Frogs' and toads' eggs can be found wherever frogs live. The eggs are usually laid in early April. Frogs' eggs are found lying in bunches in ponds. The toads' eggs are laid in long strings. Collect the eggs in large pails and take plenty of pond water with them. In the classroom or at home, keep the eggs in gallon glass jars or other large containers. Do not put the eggs in an aquarium that contains fish. The fish may eat the eggs or the young tadpoles.

Use a magnifying glass to observe the hatching eggs. Take notes and draw pictures of what you see.

2. Collect some cocoons and **chrysalids** (KRISS'l-idz) during the fall and winter months. A chrysalid is what a butterfly spins around itself. Only moths spin cocoons. Put the cocoons or chrysalids in a quart jar with sod on the bottom. Cover the top of the jar with screen or netting. Keep the sod moist. Suspend the cocoons or chrysalids in midair from a thread or twig.

When the insect appears to be emerging, remove the cocoon or chrysalid to a jar large enough for the insect to spread its wings to dry. When the insect has emerged, add to the jar a cotton ball soaked in sugar water. What happens?

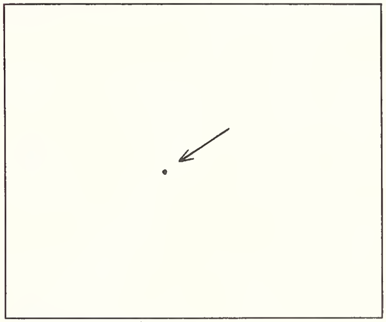


Human Growth

When you were born, you came into the world as a live baby. All animals that begin with an egg cell—elephants, rabbits, robins, whales, deer—come into the world as live babies. However, they do not start as babies; they *grow* to be babies. It takes a lot of growing to develop from an egg cell to a baby. You have probably looked at newborn babies and thought, "They seem so small." But when you began your life you were much smaller than a newborn baby. Look at the tiny spot in the picture. The spot is more than ten times larger than the egg cell with which your life began.

It may be difficult for you to realize that you started life as a single fertilized egg cell. Your development as an embryo was in some ways similar to that of the chick, except that the egg from which you developed was many times smaller than a hen's egg. It was about 1/100 of an inch wide. A microscope or a good hand lens would have been needed for you to see it.

For a single fertilized egg cell to develop into a many-celled organism, food materials are needed. In the human egg, unlike the chicken yolk, there is very little food. As you developed, you got food from your mother's body. The human embryo has its own blood system, separate from the mother's, and there is never a direct flow of blood between mother and young. The blood



The fertilized egg from which you developed was 1/10 the size of the dot in the picture.

systems of the two are separated by thin tissues made up of cells that allow an exchange of oxygen, food, and wastes.

It took two months for the different parts of your body to form. At that time, you were about one inch long. During the next seven months, you grew about 18 inches. In fact, before you were born, you grew more rapidly than you will grow during any other nine-month period in your life.

TEACHING SUGGESTIONS
(pp. 67–71)

LESSON: How do humans develop?

Background: We are concerned in this lesson with the concept that a single fertilized egg is the beginning of a new human being.

On page 75 there is a reference to a book for children's reading. *Who Do You Think You Are?* by Doctor Marguerite Rush Lerner is an excellent book on human development for children. It is one of the Prentice-Hall Junior Research Books.

Further background for the teacher can be gleaned from *Biological Science: An Inquiry into Life,* the Yellow Version of the B.S.C.S., Chapters 27 and 28.

Learnings to Be Developed:

All life stems from previous life.

Human growth is an orderly process, which is regulated by hormones.

Hormones are secreted by glands.

Developing the Lesson: Tell the class they are going to do what scientists are always doing at one time or another. Scientists collect data, or bits of information, and then see what they can learn from them. They start with questions.

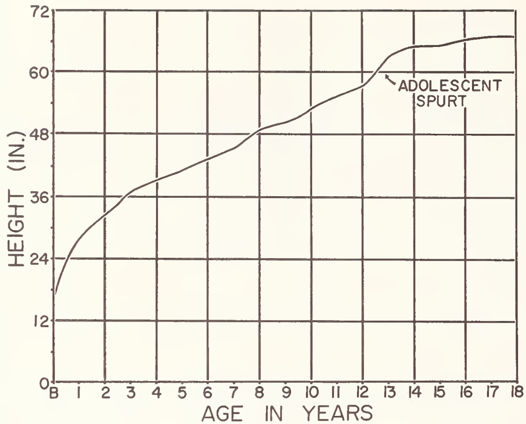
Our questions are related to human growth. We want to learn something about the growth pattern. For example:

- *What is the average height of a fifth grade pupil in this school?*
- *If there are several classes, how accurate will our figure be if we measure only one class?*
- *What is the average proportion of neck-and-head length to total height?*

Compare the body proportions of the fifth grade pupils with their parents' proportions. Compare the body proportions with those of an infant.

ADDITIONAL ACTIVITIES:

It was through library research that the vital work of Gregor Mendel on heredity was brought to light almost 50 years after it was published in an obscure Swiss journal. A scientist named Correns, while examining the literature on heredity, stumbled on Mendel's great contribution.



This graph shows one person's growth for 18 years. Make such a graph for yourself with your parents' help.

Growing Tall

People continue to grow until they are about twenty-five years old. However, people grow more rapidly during some periods than they grow during other periods.

The graph above shows the **rate of growth** of one person. The numbers running up the side of the graph stand for inches of height. The numbers across the bottom of the graph stand for years of age. During which years was his growth most rapid? During which years was it least rapid? At what age did he reach his full height? If your family has a record of your height measured at different ages, you can make a graph like this one to show your rate of growth.

The rate of growth is the amount that something grows in a certain time. Different parts of a person's body grow at different rates.

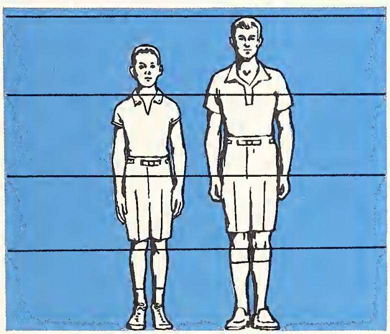
Look at the diagram on the next page which compares a boy's body with an adult's. About how much of the boy's height is taken up by head and neck? How does this compare with the body of an adult? How much of the boy's height is taken up by legs? How does this compare with the body of an adult? From this evidence, what would you say about how someone's body changes as he grows up?

Comparison of Heights

How do the heights of different parts of your body compare with the heights of the same parts of your parents' bodies?

Have one of your parents measure your total height. Then have him measure the length of your neck and head from your shoulders up. Next have him measure the length of your legs from your hips down. Record your various measurements in inches. Do a **scale drawing** showing all the measurements. You can make such a drawing by letting ⅛ of an inch represent one inch of your actual height. The scale drawing of yourself will be only ⅛ as tall as you are.

How do the heights of different parts of this boy's body compare with his father's body?



12 34

You can take your parents' measurements in the same way. After you have a record of the measurements, make scale drawings of your parents' heights. Now compare the scale drawing of yourself with those of your parents. How do your neck, head, and leg measurements compare with those of your parents?

Rates of Growth

Although most people grow until they are about twenty-five years old, their rate of growth varies from year to year. Children grow most rapidly during their first two years. After this period, the growth rate of children slows down. Girls begin to grow quickly again when they are between twelve and fourteen years of age. At this time, their rate of growth increases. They may grow as much as three or four inches each year during this two-year period. We call such rapid growth a growth spurt.

The growth spurt for boys does not generally occur until they are about fourteen years old. Usually girls have their growth spurt two years earlier than boys. This explains why twelve- and thirteen-year-old girls are often taller than boys of the same age. After sixteen years of age, boys have caught up and generally grow taller than girls.

Committees can be formed (or individual assignments made) to search out and bring in illustrations (please emphasize that they must *never* be removed from either books or periodicals, *but only copied*) and information on the development of mammalian embryos of various common animals such as the cat, dog, cow, human. (In the April 30, 1965 issue of *Life* magazine are excellent photographs of various stages of development of the human embryo. More advanced students could consult *Life*'s four-part series, "Control of Life," which began in the issue of September 10, 1965.)

Illustrated reports on the development of various body systems can be assigned. For example, the development of the digestive, respiratory, or circulatory system can be traced through the earthworm, the frog, and man. Or the class could concentrate on the development of these various systems in man alone.

Reports on the development of individual organs, such as the heart, the eye, etc., can be of enormous interest.

Reports on the pituitary gland as a growth regulator, or on the thyroid gland, which regulates metabolism, are related to the general topic of the unit.

Reports on plant hormones as growth stimulators or growth inhibitors can be developed. These hormones have been used as weed killers; some of them overstimulate the plants so that they grow and die before flowering, thus producing no seeds for the following year.

Ask each child to check on his immunization record. The parent should be able to supply the needed information. What relationship does this have to growth?

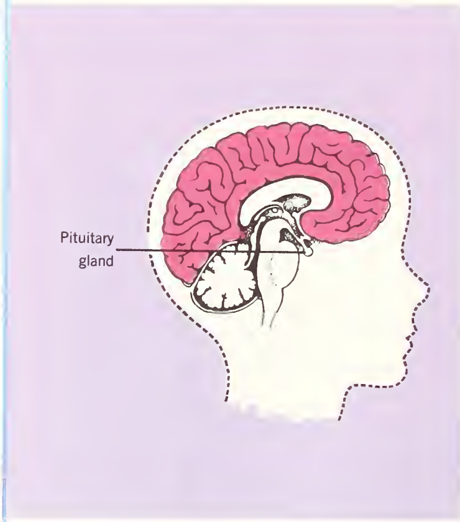
Research should be done on factors inhibiting development. Have children look up the effect on growth and development of drugs, tobacco, improper diet, lack of exercise, and childhood diseases. The school nurse might be a source of information.

Have each pupil find out his weight at birth. How many times as heavy is he now? Many birth certificates record the length at birth. Have children research their statistics and compare their growth with the chart on page 68. (The chart shows about 15″ at birth and 54″ at the age between 10 and 11. This means a height increase of 3.6 times for the chart child in fifth grade.)

Some boys and girls grow faster than others. They often stop growing early, and the slow growers may finally be taller than the fast growers.

As you grow up, you can expect another change. Your body will change its shape from that of a child to that of an adult. Usually girls begin to change earlier than boys.

Everyone has his own pattern for how much he will grow and when he will grow. You, too, have your own pattern, and it may be quite different from that of your friends.



Growth Regulators

Although people stop growing when they are about twenty-five years old, some animals and plants continue to grow for as long as they live. Can you name such animals or plants and tell how they are able to continue growing? Why do people stop growing? This is a question that scientists have not been able to answer. However, scientists do know many things about growth.

Look at the picture on this page. There is a gland located in the head just beneath the brain. This gland is called the **pituitary gland** (pih-TOO-uh-tehr-ee). It produces **hormones** (HOR-mohnz). A hormone is a chemical that causes certain things to happen in the body. A hormone travels in the blood from certain glands to parts of the body. One of the hormones produced by the pituitary gland regulates the rate at which the bones grow. Have you ever wondered why some people grow to be giants? While giants are growing, their pituitary glands produce too much hormone. This causes their bones to grow larger than normal. Sometimes the opposite thing happens. When the pituitary gland does not produce enough hormone, the bones do not grow properly. When this happens, the person is a dwarf.

Full-grown animals and people need a variety of materials to work and play and stay alive. They need these materials so that the systems of their bodies can grow, develop, and work properly.

In the next unit, you will learn more about your body. You will learn about the many systems that enable *you* to breathe, eat, move, get rid of wastes, and react to your surroundings.

Using What You Have Learned

1. Ask your school nurse for figures showing the heights and weights of children of different body builds at various ages. Make a growth graph for each build—narrow, medium, and broad.

If you cannot get such figures from the nurse, make a survey of your classmates and then make a growth graph for each classmate.

2. Plants also have growth hormones. The best known of these hormones are the **auxins** (AWK-sinz). You may be able to get an auxin at a nursery or a florist shop. Cut some branches off a plant and apply the auxin as directed on the package label. What happens? Keep a record of what you do and of what happens.

3. Look at photographs of your parents. Your parents have grown and developed through the years. Look at photographs of yourself and compare them with photographs of your parents at various ages. How is your growth pattern the same as those of your parents? Do you see any differences? Can you account for these differences?

4. Find out about the hormones in your body. How would you go about finding good sources?

After you learn about hormones, make a chart to show what each hormone in your body does.

The Journal of Public Health, Volume 36, page 1373, gives the following information on median heights and weights (50% of subjects were above or at the figure given):

Age	*Sex*	*Height*	*Weight*
10	Boys	55″	72 lbs.
10	Girls	55″	70 lbs.
11	Boys	57″	78 lbs.
11	Girls	57″	79 lbs.
12	Boys	59″	84 lbs.
12	Girls	60″	88 lbs.

TEACHING SUGGESTIONS
(pp. 72–73)

Background: These two pages constitute a review of the concepts and terminology introduced in this unit.

What You Have Learned: This is a summary of the entire unit, with new words in boldface type.

Checklist of Science Words: Remind the pupils that there is a *Dictionary of Science Words* on pages 358–364. They should consult this dictionary whenever they are unsure of the precise meaning of a word.

WHAT YOU KNOW ABOUT

Growth and Development

What You Have Learned

All living things have an orderly pattern of development. **Embryologists** study the early development of living things.

A chicken has an orderly pattern of development. The egg cell is fertilized by one of a rooster's **sperm cells.** Three cell layers form as the fertilized egg cell develops: the **ectoderm,** the **endoderm,** and the **mesoderm.** The time in which a fertilized egg cell develops is called the **incubation period.**

In flowering plants, **fertilization** takes place after the nuclei of the **pollen grain cells** join with the nuclei of the **ovule cells.** As the plant seed forms, it develops three main parts: a seed coat, stored food, and an undeveloped plant. Development of an embryo plant is called **germination.**

For a single fertilized egg cell to grow and develop into a many-celled, complex organism, it requires certain materials. Food supplies these materials. A chick embryo gets its food from the egg **yolk.** The embryo plant in a seed gets its food from materials stored in the seed. The human embryo gets its food from its mother's body.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

embryo	hormone	ovule
embryologist	larva	pistil
embryology	ovary	pituitary gland
germination	oviduct	stamen

Find the Order

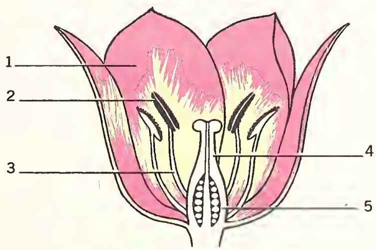
Write in your notebook the correct order of the stages in the life of a butterfly.

larva adult egg pupa

Can You Tell?

The picture shows the parts of a flower. Tell what each part is.

1. What does the pistil contain?
2. What does the stamen contain?



Complete the Sentence

Write the numbers 1 to 5 in your notebook. Next to each number, write the word or words that best fit the space in each sentence.

1. The time it takes for a complete chick to develop from a fertilized egg cell is called the __?__ __?__ .
2. The science of the early development of living things is called __?__.
3. The development of a plant from a seed is called __?__.
4. The wormlike animal stage of an insect is called the __?__.
5. A gland that produces hormones, found just beneath the brain of a human being, is the __?__.

Find the Order: Egg, larva, pupa, adult.

Can You Tell?

1. The pistil contains the ovary and the ovules.
2. The stamen contains the pollen grains.

The numbered parts of the flower are:

1. Petal
2. Pollen (at top of stamen)
3. Stamen
4. Pistil
5. Ovary (containing ovules)

Complete the Sentence:

1. incubation period (gestation period in higher animals)
2. embryology
3. germination
4. larva or larval stage
5. pituitary

(pp. 74–75)

Background: These pages reinforce the concepts presented in the unit by suggesting activities that extend the pupil's ability to apply the learnings derived from the unit.

Tell a Life Story: The missing stages on the left, moving clockwise, are egg, larva, and pupa. The missing stage on the right is the fruit.

YOU CAN LEARN MORE ABOUT

Growth and Development

What Are the Words?

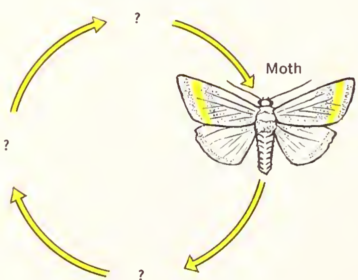
Each letter in this word is also a letter in a science word, or words, that you have learned in this unit. Find a word for each letter without using the same word more than once.

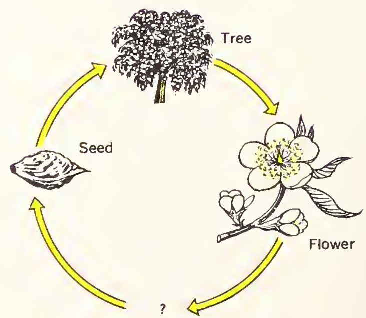
G
E
R
M
I
N
A
T
I
O
N

Tell a Life Story

Make a circle of arrows as shown in the picture on the left. Draw pictures in the spaces left by the arrows to tell the life story of a moth.

In the circle of arrows on the right we have started the life story of a peach tree. What is missing?





You Can Visit

A botanical garden has many different kinds of plants. How does a botanical garden provide the proper environmental conditions for each? How many different kinds of environments can you find?

Notice also how the hothouses are built. Is there a heating system in the hothouses? If not, why is it so warm? Are the plants in some of the hothouses moist?

Many botanical gardens show films or have talks on Saturdays. Others have special summer programs for boys and girls your age. Find out if the botanical garden you visit has such programs.

You Can Visit: Some of the children might want to bring cameras to the botanical garden. The pupils' photographs of the plants can be used to illustrate an imaginative report about the visit.

You Can Read

1. *How Things Grow,* by Herbert S. Zim. A good introduction to human growth and development.
2. *Why You Are You,* by Amram Scheinfeld. Why you look, think, and act as you do.
3. *The Man Who Found Out Why: The Story of Gregor Mendel,* by Gary Webster. Mendel's experiments as a pioneer in the study of genetics.
4. *Who Do You Think You Are? The Story of Heredity,* by Marguerite R. Lerner. Information on DNA, genes, the beginning of human life, and the development of the embryo.

KEY CONCEPTS

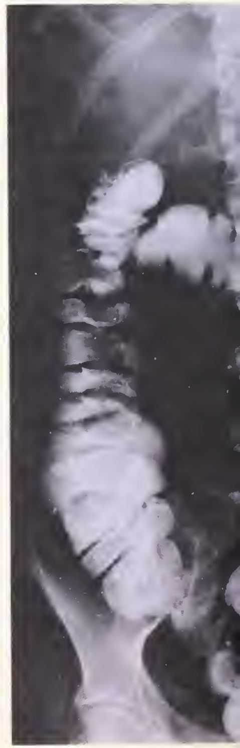
Key Concept 1. Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

Key Concept 7. When equilibrium is upset in organism-environment interactions, regulatory mechanisms go to work to restore equilibrium.

Key Concept 8. There is a relationship between structure and function; the structure of parts of living organisms determines the function of those parts.

CONCEPTS:

1. All forms of life must carry on certain activities to stay alive.
2. Scientists conduct studies to find out how environmental conditions affect life processes.
3. The circulatory system maintains a suitable environment for cells of the body.
4. By the process of digestion, food is prepared for use by cells of the body.
5. Through the respiratory system, oxygen is supplied to the blood, and CO_2 is removed.



4

Other concepts appear under "Learnings to Be Developed" in each lesson found in the Teaching Suggestions.

Systems of the Body

Keeping Alive
Adjusting to Changes
Doing Things Without Thinking

6. The excretory system removes wastes from the body.
7. Muscles and bones make it possible for the body to move.
8. Living things adjust to changes.
9. The nervous system controls body actions and helps maintain homeostasis.
10. Through experimentation, scientists have learned much about the life activities of the body.

PROCESSES:

- Observing—Pages 84, 85, 87, 88, 90, 91, 99, 100, 101, 102, 104, 105, 106, 108, 109, 111, 117.
- Experimenting—85, 99, 104, 109, 111, 117.
- Comparing—85, 91, 98, 99, 101, 104, 105, 109, 111, 117.
- Inferring—84, 85, 90, 93, 98, 99, 101, 104, 109, 111, 117.
- Measuring—85, 90, 98, 111, 113.
- Selecting (sources from recall) —90, 91, 98, 103, 106, 112.
- Demonstrating — 81, 83, 84, 85, 86, 90, 96, 98, 100, 101, 102, 106, 113.
- Explaining—99, 104.
- Hypothesizing or Speculating—98.

TEACHING SUGGESTIONS
(pp. 78–79)

LESSON: What do we know about living things?

Learnings to Be Developed:

All forms of life must carry on certain activities to stay alive.

Scientists conduct studies to find out how environmental conditions affect life processes.

Developing the Lesson: List on the board the processes essential to life. Ask pupils to mention parts of the body (organ, tissue) that serve each function. Review the relationship between organs and life processes (structure and function) in Unit 2 (pp. 38–39).

- *What happens to your breathing if you run to school?*
- *Do you notice any change in your heartbeat?*
- *Why is it important to have healthy teeth?*
- *Are muscles "used" only during exercise?*

Pupils may know the answers intuitively or from their observations. They may wish to test their answers by simple experiments. Point out that these questions will be studied in subsequent lessons of this unit.

Man has invented machines that do amazing jobs. Nuclear-powered submarines travel the world without surfacing even once! Electronic "brains" can solve more arithmetic problems in two minutes than your whole class can do in two months. Yet no machine is as amazing as the human body.

Keeping Alive

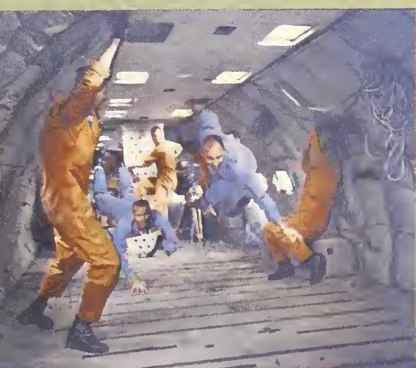
Think of the activities going on right now inside your body. Your digestive system is working to change the food you ate so your body can use it. Your heart is pumping blood to all parts of your body. Your muscles are keeping you in an upright position. You are also breathing, getting rid of wastes, using hundreds of muscles, and doing much more. And while all these activities are going on you are also learning about science as you read this book.

Jacques Piccard went to a depth of 35,800 feet in the bathyscaphe Trieste, built by his father, Auguste Piccard. Colonel John Stapp rode in a rocket that went over 630 miles an hour. Pilot Joseph Walker traveled to a height of 354,200 feet in the X-15 test plane. Twenty years ago, men could not have done these things. They could not because scientists did not know enough about how man's body works.

How long can man go without food? How long can man go without sleep? Astronaut Alan Shepard is undergoing tests to help find out.

The purpose of this test is to find out how the body withstands increases in heat.

These men are floating in air. They are finding out how weightlessness affects the body. Why do you think they want to know?



All these experiments and hundreds, even thousands, more give scientists information about the workings of the human body. Still, there is much that scientists want to know.

Have the class look at the pictures on these pages. You may want the class to turn to page 316 to see a photograph of the *Trieste,* to page 291 to see Colonel Stapp's rocket-propelled sled, and to page 304 to see the X-15 plane. Relate the pupils' own experience to the cause-and-effect relationships that scientists seek when they study the human body.

- *Is your breathing different in a mountain area?*
- *Have you experienced the feeling that your ears were "closing" riding up a hill or in an airplane or elevator?*
- *What happens when you go down quickly?*
- *What happens to your ears when you swim under water?*

At high altitudes there is less oxygen, and you breathe more quickly and deeply to get enough. Air pressure also changes at different altitudes. When you go from one pressure area to another, blood pressure and heartbeat may change. The increased pressure of the ocean depths also affects blood pressure. Pilots who fly at high altitudes and at great speeds must wear oxygen masks and pressure suits.

TEACHING SUGGESTIONS
(pp. 80–82)

● **LESSON:** Why is blood called the body's lifeline?

Learnings to Be Developed: Blood carries food and oxygen to body cells and removes wastes from cells.

Background: The idea that blood circulates in a continuous pattern through arteries and veins was suggested over 300 years ago by the English scientist William Harvey (1578–1657). Anton van Leeuwenhoek (1632–1723) proved this idea with his microscope. When he examined a fish under his lenses, he saw blood flowing through little vessels in the fish's tail. He was able to identify the red blood cells. Students can repeat what Leeuwenhoek did, and see the circulation of blood in a goldfish (see Follow-Up, p. 82).

The bloodstream has been likened to a transportation system. Extend this analogy to describe all the parts in the human circulatory system before starting the lesson. Put a schematic drawing on the board. The blood "travels" throughout the body on main routes—the *arteries* and *veins*. It travels on branch routes, the *arterioles* and *venules*, smaller vessels which branch out from the

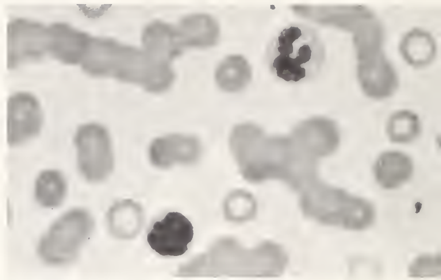
All forms of life must carry on certain activities to stay alive. Lower forms of life, such as the ameba, carry on the activities of getting food and oxygen and getting rid of wastes in very simple ways. The one-celled animal has only one cell which carries out all these activities. Man has several complicated systems, each with a certain job to do. In this unit, you will find out about the various systems of the human body and how they work to maintain life.

Blood—Your Body's Lifeline

There are many different kinds of transportation systems in the world. There are trains, buses, automobiles, airplanes, and even, today, rockets. But the most wonderful transportation system is right in your own body. It is the bloodstream.

The bloodstream carries everything the cells need to maintain life. It is in the cell that the work of maintaining life goes on.

Cells use food and oxygen. They need to get rid of wastes. How do cells get food and how do they get rid of wastes? Every cell in the body is very close to tiny blood vessels. These blood vessels bring food and oxygen to the cells and carry away waste materials. Blood vessels do not actually touch the cells, but fluids from the blood seep into the spaces around the cells. Each cell is bathed in these fluids and absorbs food from them.



Blood as seen under a microscope. Can you identify the white blood cells?

As the blood **circulates** (SER-kyoo-layts), or moves, through the body, it picks up products from one part of the body and carries them to another. Oxygen, for example, is carried in the blood from the lungs to every cell in the body. Hormones are carried in the bloodstream from glands to certain cells. The blood carries food from the intestines to cells throughout the body. Each cell absorbs, from the bloodstream, what it needs. Now do you see why the bloodstream is sometimes called the "river of life"?

Simple animals like sponges do not have a bloodstream. However, they still need to have materials circulated to all

parts of the body. The materials they need to circulate are in the form of molecules. Molecules are always in motion. They move in all directions until they are spread evenly throughout the space available. If there are many molecules in one spot, then some molecules will move to where there are not so many. The movement of molecules from a place where there are many to a place where there are fewer is called **diffusion** (dih-FYOO-zhun). Sponges take in water through their pores and filter out bits of food in the water. Then, through diffusion, the food is circulated.

Try this to see how diffusion takes place. You will need a glass of water and some ink (India ink is easiest to see). Add a drop of the ink to the water. Describe the way in which the ink moves through the water. Use a magnifying glass for a closer look.

Some simple animals have a circulatory system, but one that is simpler than the human system. An insect such as a mosquito has a blood system. The system is called an "open" one. The blood vessels open directly to the body cavity, where the heart and other organs are bathed in blood.

All animals with backbones have a more complicated circulatory system. It is made up of a heart and vessels of various sizes that carry the blood.

All the life activities of a sponge depend on a continuous flow of water through its porous body. This flow of water is the sponge's only means of getting food and oxygen and getting rid of wastes.

An insect, such as a grasshopper, has only one blood vessel, with openings through which blood enters. From one end of the vessel, blood drains into the head and body, carrying food and picking up wastes.

arteries and veins. It travels into the *capillaries*—intersections or connecting bridges between arteries and veins. From the capillaries it *diffuses* to body cells. Central to this system is the *heart*, which "signals" all incoming and outgoing blood. Veins carry blood to the heart, arteries carry blood away from the heart. The veins and arteries, venules and arterioles do not merge.

Developing the Lesson: Have the class describe what they see in the picture on p. 80.

- *Where else in this book have you seen a picture of blood cells?* (On p. 37.)
- *Why is blood red?*

Blood consists of two parts—a fluid, or *plasma*, and cells, called corpuscles, suspended within the plasma. The red cells contain hemoglobin, which makes blood appear red. Red cells are round (disk-shaped). They carry oxygen to cells of the body. White cells are ameba-like in shape. They help to defend the body against infection.

Some pupils may ask why, after a wound, blood clots and a yellow fluid appears. You may want to introduce the terms *coagulation* and *serum*. The yellow serum is mainly water. It contains hor-

mones, enzymes, and nutrients (minerals, vitamins, proteins). Serum also contains waste products from the body cells, and antibodies, produced by the white cells when they fight infection.

Follow-Up: Show how blood circulates in a healthy goldfish. Wrap wet absorbent cotton around the fish, leaving only the tail exposed. Place the tail between two slides. Examine the tail under the low power of a microscope. Let the children describe the movement of red blood cells inside the fish's tiny arterioles and venules.

Which vessels carry blood to the heart? Away from the heart?

Which vessels branch off arteries?

Which vessels branch off veins?

Which vessels carry blood from arteries to body cells and from body cells to veins?

Which vessels are thinnest?

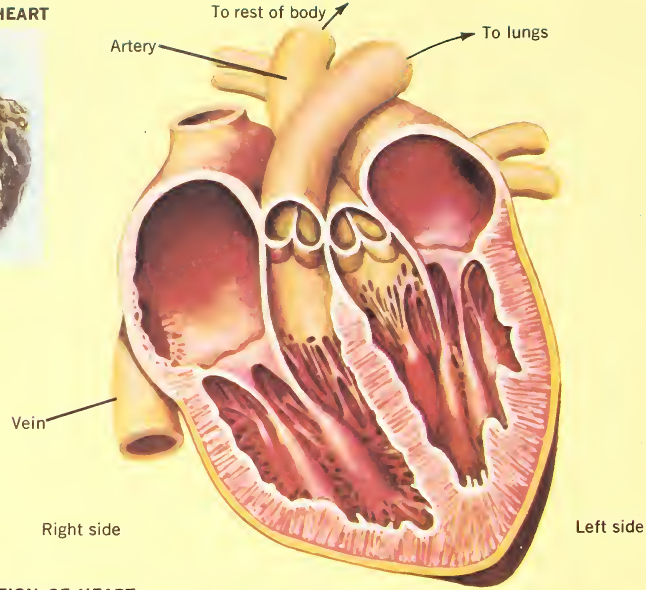
What kinds of cells are in blood?

What do body cells need from blood?

What do cells need to get rid of?

How do these substances pass between body cell and blood cell? (Diffusion.)

THE HUMAN HEART



PUMPING ACTION OF HEART

1. Blood enters the right side of the heart from all parts of the body. At the same time, blood from the lungs enters the left side of the heart.

2. Blood from the right side flows into the bottom half of the right side. Blood from the left side flows into the bottom half of the left side.

3. The bottom half then squeezes, pumping the blood from the right side to the lungs and the blood from the left side to the rest of the body.

Your bloodstream is like a river with many, many branches. But while rivers flow only downhill, your blood flows up as well as down. A pump is needed to keep pushing the blood through your body. That pump is the heart. No pump made by man can compare with your heart. Your heart pumps blood for as long as you live.

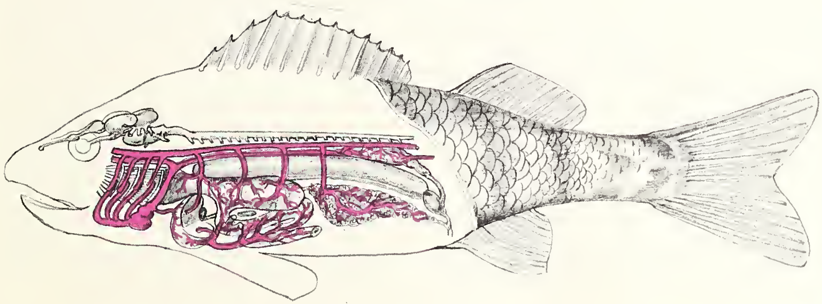
The Heart

Your heart is really a double pump. The right side is one pump, and the left side is the other. The right side pumps blood to the lungs. The left side pumps blood to the rest of the body.

Most animals have a heart that pumps blood. Even the ant has a heart! However, its heart is only a long, muscular tube. From this tube, blood moves forward in waves as the muscles of the heart first contract and then relax. Fill a long, narrow hose with a liquid, such as water. Then use the muscles of your hand to squeeze the hose. You will see how the ant's heart muscles move blood along. The muscles must relax before the next big squeeze, or contraction. The movement along the tube is a wave-like contraction and relaxation.

The fish has a more complicated heart than the ant has, but the fish's heart still does not have two sides as your heart does. The fish's heart sends blood through a large blood vessel to the gills. There the blood picks up oxygen, and then the blood goes to vessels that carry it to all parts of the body. The blood is never pumped directly from the heart into the body of the fish.

The heart of a fish is found near its throat. Red lines shows the circulatory system in a fish. How does circulation in a fish compare with that in an insect?



TEACHING SUGGESTIONS
(pp. 83–84)

LESSON: How does the heart work?

Learnings to Be Developed:

The heart is the organ that pumps blood through the body.

Heart muscle contracts and relaxes in a rhythmic beat called the heartbeat.

Developing the Lesson: Have the class study the diagram on p. 82. Locate the areas of the heart (upper, lower, right side, left side). Locate the *aorta* (main artery); locate the *pulmonary artery*, which goes directly to the lungs. Introduce the term *chamber*. Point out that the upper part has two chambers called *auricles*, and the lower part has two chambers called *ventricles*. What else can the class tell about the structure of the heart?

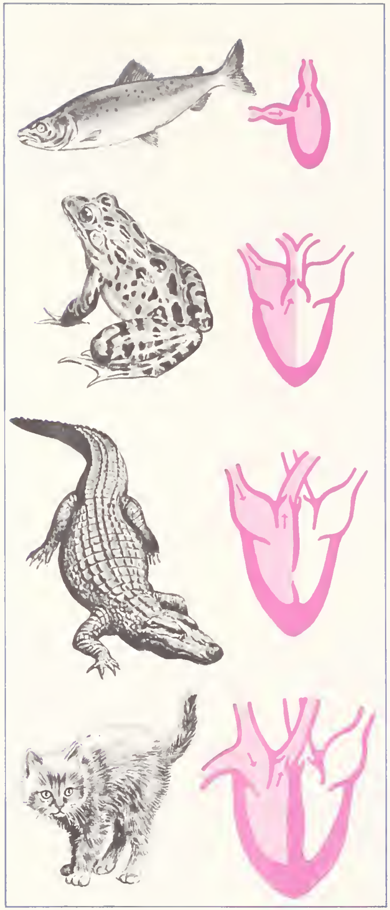
- *Where does blood enter the heart?* (Auricles, upper chambers.)
- *Where does blood from the lungs enter the heart?* (Left auricle.)
- *What artery goes directly to the lungs?* (Pulmonary.)
- *When the ventricles contract, what happens?* (Blood is

pumped out of the heart via arteries.)

- *How many chambers does the human heart have?* (Four.)

Follow-Up: Have children locate the pulse in their wrist. If a stethoscope is available, let them check their heartbeat and compare it with the pulse beat. Show the effect of mild exercise.

- *Does the pulse beat change? Is it faster or slower?*
- *Does the heartbeat change?*
- *What can you tell by comparing the rates of heartbeat and pulse beat?*



How do the hearts of these four classes of vertebrates differ? Why isn't a bird's heart shown? What kind of heart do birds have?

It is only in creatures such as birds and mammals that we find the heart divided into two separate halves. One side has blood with oxygen in it. The other side has blood that must be pumped to the lungs to pick up oxygen. There is no mixing of the two kinds of blood in this type of heart.

Look at the picture of the human heart. It is about the size of your fist. Do you see the tubes that lead away from it? They are called blood vessels. There are three kinds of blood vessels. The **arteries** (AHR-ter-eez) carry blood away from the heart. The arteries branch into **capillaries** (KAP'l-ehr-eez). The capillaries are the thinnest blood vessels in the body. They are only one cell thick. Can you tell why they are so thin? How would you find out? The capillaries must be able to carry the blood to every body cell. The **veins** (vaynz) carry blood back to the heart from the capillaries. You can see some veins in your hands and arms. They look bluish.

You can feel the pumping action of the heart. There are some places in the body where an artery is close to the skin. One such place is the inside of your wrist. Another is your neck. You can feel the heartbeat in these arteries. The beat in an artery is called a **pulse.**

Doctors use the artery in the wrist to count your pulse. You can do the same. Hold the first two fingers of your right hand lightly against the inside of your left wrist in line with the left thumb. Do you feel a beating? Use a stop watch or a watch with a second hand to count the number of beats in one minute. How fast does your heart beat? Now stand up straight and touch the floor ten times, bending from the waist each time. Count the number of beats again. How does the second count compare with the first?

Why does exercise cause your heart to beat faster? The muscles in your legs and arms and other parts of your body have been relaxed. Suddenly you exercise by moving up and down to touch the floor. Your muscles must now work hard. These muscles need more food and oxygen quickly. The blood brings the food and oxygen to the muscles. The blood supply must be increased to carry the extra load. The heart speeds up its beating from about 100 beats per minute to 120 beats or more. After you have finished exercising, the muscles no longer need a big blood supply. The heart goes back to its normal beat. This all happens without your having to think about it. It happens automatically. Imagine if you had to remind your heart to speed up or slow down all the time!

When you go to the doctor's office, he usually listens to your heartbeat. He does this by using a **stethoscope** (STETH-uh-skohp). What does the doctor hear?

TEACHING SUGGESTIONS
(p. 85)

● **LESSON:** How does the human heart compare with that of other animals?

Learnings to Be Developed:

The heart has evolved from a simple tube to a complex four-chambered organ.

The structure of the human heart provides for the most efficient circulation of blood.

Developing the Lesson: Have pupils study pictures on page 84. You may also use chalkboard diagrams.

- *How are the amphibian and reptile hearts alike? How are they different?*
- *Which heart is most like ours? Why is this an advantage?*

The amphibian and reptile both have three-chambered hearts. In some reptiles the third chamber is divided completely. The cat (mammal) has a four-chambered heart, like ours; the right side is completely separate from the left. There is no mixing of blood. Pure blood—blood with fresh oxygen from the lungs—is pumped directly to cells. The bird's heart is four-chambered, like the mammal's.

TEACHING SUGGESTIONS
(pp. 86–87)

LESSON: Why must food be digested?

Background: Review *cell membrane* (p. 33), *diffusion* (p. 81), and *dissolving* (pp. 34–35).
Sugar molecules dissolve readily in water, but starch, proteins, and fats cannot. They must be broken down to pass into the bloodstream through the lining of the small intestine. Sugar goes to our cells to be used for energy. Proteins are used for growth and repair of body tissues. Proteins and fats can also be used for energy if necessary.

Learnings to Be Developed: Through digestion, food is prepared for use by cells of the body.

Developing the Lesson:

- *Can the solids you eat diffuse into the bloodstream and cells?*
- *Can the liquids you drink diffuse into the bloodstream and cells?*

If pupils answer "yes" to the second question, point out that the starch in liquids must be broken down into sugar, which dissolves. Review the terms starch and sugar. Be sure the class knows

If your heart is normal, he hears rhythmic clicks and thumps. If there is something wrong, he may hear irregular clicks and thumps. If there is a leak, he will probably hear a swishing sound. The normal heart sounds something like "lub-dub—lub-dub—lub-dub."

The stethoscope is really a very simple instrument. It is merely a flexible tube which transmits sounds. Actually, you can hear these sounds by placing your ear snugly against the skin of another person's chest.

In 1819, a young physician named Théophile Laënnec (lay-NEK) wanted to listen to the heartbeat of a sick girl. She was very heavy, and a thick layer of fat blanketed the sounds of her heart. That afternoon, as Dr. Laënnec was strolling through a park, he came upon some boys bending over a long wooden beam. They had their ears tightly pressed against one end of it. At the other end, another boy was tapping lightly on the beam. Laënnec saw the solution to his problem. When he returned to the hospital, he rolled some papers into a tube. He placed one end of the tube to the girl's chest and then placed his ear at the other end of the tube. Läennec heard the girl's heartbeat more clearly and crisply than he had before.

Day after day, Dr. Laënnec passed through the wards of the hospital with his paper tube tied with strings, listening to hearts and carefully making notes. Because paper tubes did not last long, Laënnec made a tube of wood. He gave the instrument a Greek name, stethoscope, which means "chest examiner." As time went by, Laënnec's stethoscope was improved. Today, the stethoscope is as much a part of the doctor as the bag in which he carries his instruments.

You can make a stethoscope by rolling up a piece of paper and slipping a

Théophile Laënnec invented the stethoscope.

rubber band around it. Put one end of the tube to another pupil's chest and the other end to your ear, as in the picture. What do you hear? Sounds come through a doctor's stethoscope more clearly. With a glass Y-shaped tube, rubber tubing, and a funnel, you can make a stethoscope.

Digesting Your Food

Late in the nineteenth century, scientists knew very little about what happens in the body of a living person. Operations were not common, because they were nearly always fatal. Direct observations of what goes on inside the body were rare until quite recently.

In 1822 a strange thing happened. A trapper named Alexis St. Martin was accidentally shot in his left side. He was brought to William Beaumont, a doctor in the United States Army. The doctor patched the wound as best he could, but it never closed properly. Instead, the wall of the stomach healed by growing to the skin and muscles of the body wall. This left a hole in the left side of St. Martin's body that led to the inside of his stomach. The hole provided Dr. Beaumont with a "window" to observe and study the workings of the stomach. St. Martin co-operated with Dr. Beaumont, and the doctor was able to make many observations over a period of eleven years.

Dr. Beaumont saw that the stomach gives off a fluid. He put some of this fluid on meat and found that the meat was partly digested. He also saw the stomach move and churn when food was in it. He did many experiments and learned much about the stomach. Dr. Beaumont's experiments led the way for other scientists to make many more discoveries about how the stomach digests food. What you will read here about the digestive system is the result of the

they are different. (But both are carbohydrates.) Let the class compare a starch suspension and a sugar solution.

- *Which is thicker? Which is cloudy?*
- *Has the starch dissolved?*

Suggest the following experiment. Put a pinch of cornstarch in one test tube, sugar in another. Add water, about halfway up the tubes, and shake. Cover the mouth of each tube with a semipermeable membrane. (A semipermeable membrane may be obtained from a biological supply house.) Tie the cover tightly with rubber bands. Invert each tube in a separate beaker of water. In 20 minutes test the water in first beaker for starch. (Iodine turns starch blue.) Test water in second beaker for sugar. (Add Benedict's solution and heat; if sugar is present, solution turns green to brown.)

- *Did the color of the water in the first beaker change?*
- *Did the color of the water in the second beaker change? Why?* (Starch was not present in the first beaker; therefore it did not diffuse through the membrane. Sugar was present in the second, and it diffused.)

TEACHING SUGGESTIONS
(p. 88)

● **LESSON:** Where does digestion begin?

Learnings to Be Developed:

Digestion starts in the mouth. The teeth break up food into small bits when you chew.

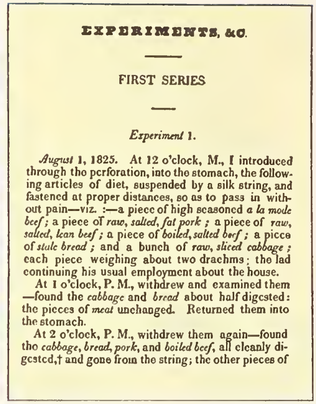
Saliva changes starch to sugar.

Developing the Lesson: Review bone tissue (pp. 36, 37). Have the class look at the diagram on page 89.

- *What do teeth do?*
- *Where are the salivary glands?*
- *Name foods that contain starch and sugar.*

Explain that sugar and starch are both carbohydrates. Because starch does not dissolve, it must be changed to sugar. Saliva in the mouth changes starch to sugar. (The *enzyme* in saliva responsible for this change is *ptyalin*.)

Follow-Up: Show that saliva changes starch to sugar. Put a starch-water mixture (suspension) into a test tube, add saliva, and cover with membrane. Invert the tube in a beaker containing a little water. After 20 minutes test for the presence of sugar (add Benedict's solution and heat).



EXPERIMENTS, &c.

FIRST SERIES

Experiment 1.

August 1, 1825. At 12 o'clock, M., I introduced through the perforation, into the stomach, the following articles of diet, suspended by a silk string, and fastened at proper distances, so as to pass in without pain—viz. :—a piece of high seasoned *a la mode beef*; a piece of *raw, salted, fat pork*; a piece of *raw, salted, lean beef*; a piece of *boiled, salted beef*; a piece of *stale bread*; and a bunch of *raw, sliced cabbage*; each piece weighing about two drachms; the lad continuing his usual employment about the house.

At 1 o'clock, P. M., withdrew and examined them—found the *cabbage* and *bread* about half digested: the pieces of *meat* unchanged. Returned them into the stomach.

At 2 o'clock, P. M., withdrew them again—found the *cabbage*, *bread*, *pork*, and *boiled beef*, all cleanly digested,† and gone from the string; the other pieces of

Dr. William Beaumont studied digestion by observing the process through an opening in Alexis St. Martin's side. On the right is a page from Dr. Beaumont's book published in 1833 reporting many experiments he was able to make.

work of hundreds of scientists over many years. But there is still much to be learned.

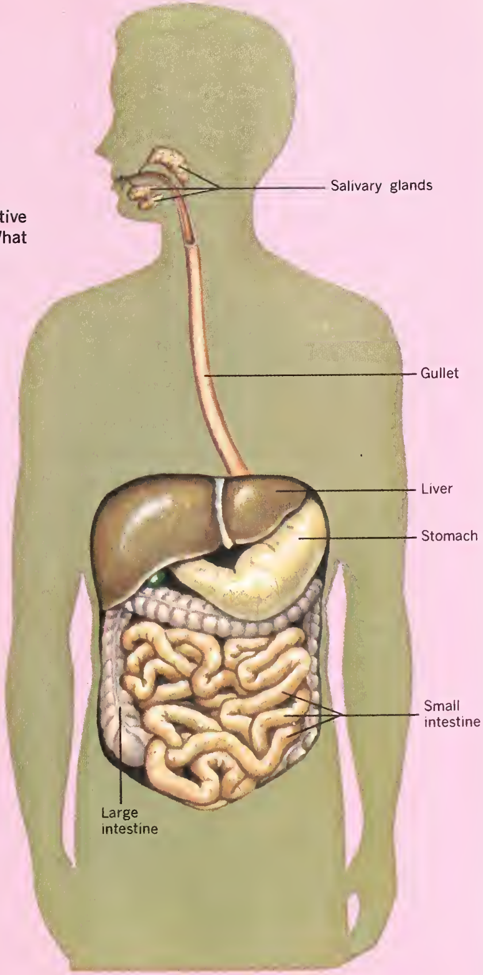
Look at the X-ray picture of your **digestive system** (dih-JESS-tiv). When you swallow some food, it goes down the **gullet** (GUL-it) into the **stomach** (STUM-ik) and then into the **small intestine** (in-TESS-tin). Whatever is not digested leaves the body by way of the **large intestine.** You may think that the food makes a rather quick trip through your body. But actually scientists have learned that the process of digesting food and getting rid of wastes takes about twenty-four hours.

What has to be done to the food so that your body can use it? You know that your body is made up of billions of cells. All of these cells need food to stay alive. How do all these cells get food? Blood carries food to the cells. But it cannot carry a piece of hamburger or a piece of potato or celery. Can you tell why? All of the solid foods that you eat have to be changed. Changing them so that they can be carried to your cells is the work of the digestive system.

The work of breaking down your food begins in your mouth. As you chew, your food is mixed with **saliva** (suh-LY-vuh). In your mouth are tubes

THE DIGESTIVE SYSTEM

The X-ray picture shows part of your digestive system. Look at the diagram at the right. What can you now identify on the X-ray picture?



TEACHING SUGGESTIONS
(pp. 89–90)

LESSON: How are proteins and fats digested?

Background: After reading the text on pages 87–88, pupils should have an appreciation of the way scientists work. Dr. Beaumont's experiments led the way for many more discoveries about digestion in the *stomach*. The fluids, or stomach juices, that Dr. Beaumont studied included hydrochloric acid and the *enzyme pepsin*. There are various enzymes in the *small intestine*. Proteins and fats are broken down into tiny fragments so that they can pass through the intestinal wall to the bloodstream. The blood carries this food to the cells. The *liver* also helps in the digestion of fats.

Learnings to Be Developed:

Proteins and fats are digested in the stomach and small intestine.

Enzymes break down proteins and fats into tiny fragments.

Digested food passes into the bloodstream through the lining of the small intestine.

Developing the Lesson: Have the class study the diagram on page 89 and the pictures on page 91.

- *Where is the stomach in relation to the small intestine?*
- *Where is digestion completed?*
- *Does digestion take place in the large intestine?*

Develop the idea that enzymes act on proteins and fats, breaking them down into tiny fragments that can pass through the villi into the bloodstream.

Let pupils participate in showing how enzymes break down protein. Ask pupils to bring in boiled eggs and fresh or frozen pineapple juice. Put chopped egg white in a test tube and add the juice. Allow the test tube to stand tor about a day in an incubator at 37° C. (about 99–100° F., the temperature in the stomach). Pupils will observe that the egg white is broken up and appears to be dissolved in the juice. Compare with a test tube containing boiled pineapple juice. (Boiling should break down the egg faster.) The enzyme in pineapple juice which breaks down protein is *bromelin*. Papaya juice contains *papain,* which also breaks down protein. (It is the chief ingredient of most meat tenderizers.)

through which the saliva flows. Saliva comes from **salivary glands** (SAL-uh-vehr-ee). Did you ever smell a pie just out of the oven or bacon sizzling on a stove? Did your mouth water? This watering is called salivating.

After chewing carefully, you swallow a small ball of food, which is moved along through the gullet to your stomach. Here the food stays for some time while it is churned. Juices from the stomach are mixed with the food. These juices help break down the food. What do you think the churning does to the food?

After a while, the food is moved on to your small intestine. Here more juices are mixed with the food. It is in the small intestine that digestion is completed.

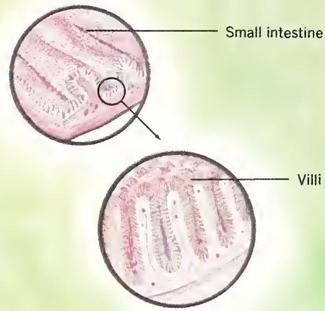
Suppose you ate celery and potatoes with your dinner. There are some parts of the celery and potatoes that you cannot digest. These parts are the cell walls of celery and potato. The cell walls of plants are made of cellulose. Your body cannot break down the cellulose. This undigested part of the food passes into your large intestine. The water in the food passes through the large-intestine wall into your blood. Other undigested food collects in the lower part of the large intestine and finally passes out of the body through the **anus** (AY-nuss). Doctors say it is important to get rid of food wastes regularly—once a day or once every two days. Sometimes people cannot get rid of wastes regularly. This condition is called **constipation** (kon-stuh-PAY-shun). Many people can correct this condition by eating more foods, such as celery, that contain **roughage** (RUF-ij). Roughage cannot be digested. As the muscles in the large intestine push it along, wastes are carried with the roughage out of the body. If constipation continues for a while, see your doctor.

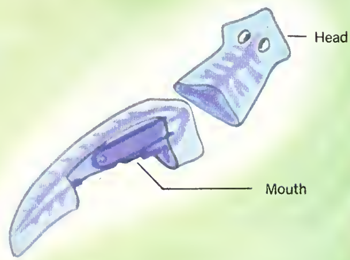
Look again at the diagram shown on page 89. The small intestine looks like a jumbled ball of rope. To get an idea of how long the small intestine is, unravel a piece of cord or rope 20 feet long while another pupil holds one end. Start at the front of the classroom and walk toward the back as you unravel the cord. Now do you see how long 20 feet is? In the adult, the small intestine is 20 feet long, and the large intestine is 4 to 5 feet long. You may wonder why the small intestine is not called the large intestine. The small intestine gets its name because it is not as wide around as the large intestine. In the illustration, you can see the difference in width between the large and small intestine.

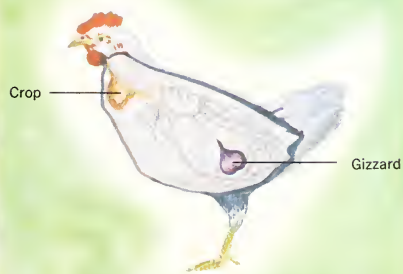
Remember that digestion is completed in the small intestine. That means that when the food leaves the small intestine it goes to the cells. How does the food get to the cells? Look at the lining of the small intestine in the picture at the right. See all the little "fingers." They are called **villi** (VIL-eye). Inside each one are blood capillaries. Digested food passes into the bloodstream by means of these capillaries. The blood carries food to the cells.

Some simple animals digest food in a very uncomplicated way. In a planarian (pluh-NAIR-ee-un), food passes from the mouth directly to an opening inside the body. Nearby cells release chemicals into the opening. These chemicals prepare the food for use by the planarian's body. Food that is not digested leaves the body the same way it came in—through the mouth.

Chickens and other birds have a more complicated digestive system than the planarian. Have you ever examined a chicken that has not been cleaned? Perhaps you have seen the **crop,** where food is stored. You may also have seen the **gizzard,** where food is ground against small stones to prepare it for digestion. Study the diagram. How is the digestive system of the chicken like that of mammals? How is it different?







TEACHING SUGGESTIONS
(p. 91)

● **LESSON:** How does muscular movement aid digestion?

Learnings to Be Developed: Muscular movements push food particles through the digestive tract.

Developing the Lesson: Have the class look at the diagrams on page 89. Ask pupils if they have ever swallowed food "whole," without chewing it enough. Let them describe what they felt.

- *What is swallowing? Locate the throat on the diagram on page 89.*
- *How does food get into the stomach?*
- *What happens to undigested food?*

○ **ADDITIONAL ACTIVITIES:**

Secure charts, diagrams, or models of the digestive tracts of fish and frog. Refer to the diagram on page 89. Compare the position and size of the organs. Observe the relative proportions of organs in each system. Note the increased length of the small intestine in the human. This indicates its importance in digestion. Point out the pancreas gland, whose hormone *insulin* works in the regulation of body sugar.

TEACHING SUGGESTIONS
(pp. 92–93)

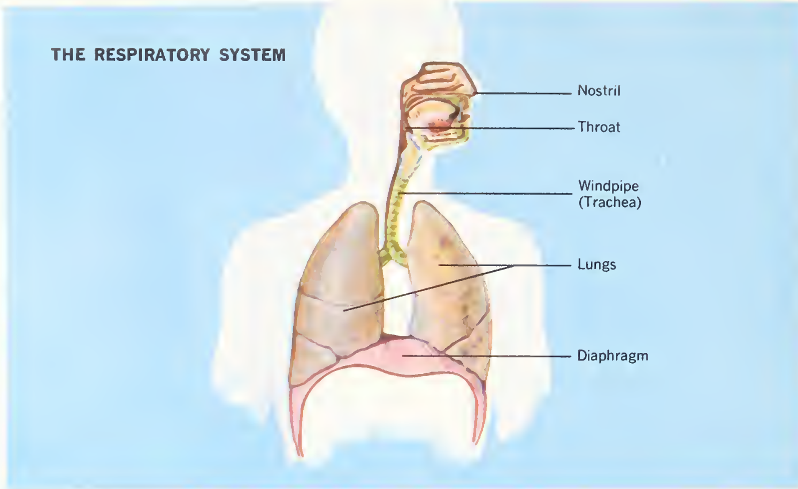
● **LESSON:** What happens to oxygen in your body cells?

Background: Pupils know that air contains oxygen and that blood carries oxygen to the body cells. Do they know how oxygen gets into the bloodstream? They may remember from their study of circulation the role played by the *lungs*. Have the class study the picture on page 93. Elicit the fact that oxygen gets into the bloodstream via *air sacs* in the lungs. Pupils also learned in their study of digestion that starch is broken down to sugar, and that dissolved sugar can diffuse into the body cells. But pupils probably do not know what actually happens to the sugar and oxygen once diffused into the cell. All these learnings lead up to this lesson.

Learnings to Be Developed: Oxygen combines with sugar in cells to produce energy for the body.

Developing the Lesson: Suggest an analogy between burning and what happens in the cell. Place a lighted candle on the desk and cover it with a glass bottle.

• *What happens?*



Trace the path of air into and out of the body, using the diagram. What role does the diaphragm play in breathing? What keeps the food you eat from entering the windpipe when you swallow?

What Happens When You Breathe

You need more than food to stay alive. You need oxygen.

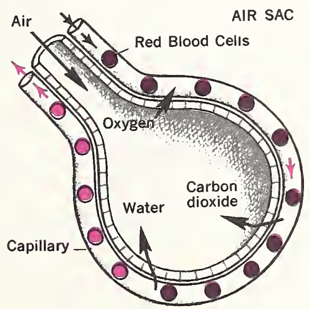
How do the cells get oxygen? Again, the bloodstream serves as the means of transportation. It carries oxygen to every cell. Now you will find out how oxygen gets into the bloodstream. This work is carried on by the **respiratory system** (rih-SPYR-uh-tor-ee).

If you were able to look inside your body, you would see a **windpipe** with two branches, each going to one of your lungs. You would also see a **diaphragm** (DY-uh-fram). Look at these parts in the picture.

Every time you take a breath, your diaphragm goes down. This action pumps air into your lungs. When you breathe out, the diaphragm goes up and the air in your lungs is pushed up through your windpipe and then out through your nose. Your diaphragm goes up and down over 20,000 times a day, about 16 times every minute, without your having to think about it.

Look again at the picture showing the windpipe. See how it branches in two. Each branch goes into a lung. Inside each lung, each branch branches again and again and again into many, many smaller branches. At the ends of the smallest branches are air sacs that look like tiny balloons.

The lungs contain millions of these air sacs. The smallest branches pipe air into and out of the air sacs. The air sacs are only one cell thick. They are so very small that you need a microscope to see them. Around each air sac are capillaries carrying blood. Now you can tell how oxygen gets into the bloodstream and how the bloodstream delivers carbon dioxide, a waste product, to the lungs.



Oxygen passes out of each air sac into the capillaries that surround it. Carbon dioxide and water pass from the capillaries into the sac and are removed when you breathe out.

The blood cells shown are red blood cells.

Getting Rid of Wastes

Things that you do not need or want, you throw away. Your mother throws the bones of chicken, meats, and fishes into the garbage pail. The food the family left from breakfast, lunch, and dinner may also be thrown away. Every day the garbage pail is filled and emptied into an incinerator or the garbage is put outside to be collected. What would it be like if you did not get rid of these wastes? What if there were no way of getting rid of the sewage, the dirt, and the rubbish of your city? Your city would not be a very healthful place.

Your body would not be very healthy if it did not get rid of wastes all the time. If your body did not get rid of them, these wastes would poison your cells. Certain diseases occur because the body cannot get rid of wastes. The wastes gather in the tissues. They affect the normal working of the body. Your body gets rid of wastes by way of the **excretory system** (EKS-krih-tor-ee). Again, your bloodstream serves as the means of transportation.

You already know two ways in which your body gets rid of wastes. Your lungs give off carbon dioxide when you breathe out. Roughage and bacteria wastes from your intestine leave the body by way of the anus.

- *Is this evidence that oxygen is essential to burning?*
- *What actually burns in the flame?*
- *Name other substances that burn.*
- *How are these like sugar?*

The wick and all other materials that burn contain *carbon* and *hydrogen*. Sugar contains *carbon* and *hydrogen*—it is a carbohydrate. Therefore sugar burns.

Summarize on the chalkboard the reactions for burning in the candle and burning in the cell:

oxygen + wick(carbon,hydrogen) = carbon dioxide + water + heat

oxygen + sugar(carbohydrate) = carbon dioxide + water + heat

- *How are these reactions alike?*
- *What is the final product in each reaction?*

Light another candle to show that water and heat energy are produced in burning. Bring the flame near the board. Let a pupil exhale on the board a few feet from the candle.

- *What forms at both spots on the board?*
- *Can you feel the heat from the flame and from your breath?*

TEACHING SUGGESTIONS
(pp. 94–95)

● **LESSON:** Why must the body get rid of wastes?

Learnings to Be Developed:

Wastes poison cells and may cause disease.

Wastes are discharged from the body by the excretory system.

Developing the Lesson: Have the class study the diagram on page 94.

- *What organs aid excretion?*
- *What organ not shown in this diagram aids in excreting solid wastes?*
- *What special structures do the kidneys have? What do they do?*

Have the class look at the pictures on page 95.

- *What are the sweat glands?*
- *Where are the pores?*

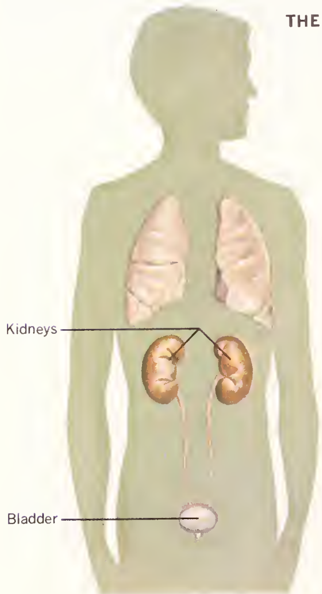
Review the fact that water and other wastes in the form of sweat get to the surface of the skin through the pores.

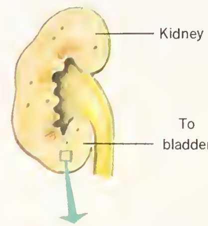
Wastes from your cells enter the bloodstream and are carried to the **kidneys** (KID-neez). Look at the picture to see where your kidneys are located. Notice that there are two kidneys. Each kidney is attached to the **bladder** (BLAD-er) by a long tube. Inside each kidney are many hollow tubes that curl around and around. Each tube ends in a cup. Inside the cups are masses of capillaries. The cups with their tubes and capillaries act as little **filters.** A filter is like a strainer. It lets certain things through but not others.

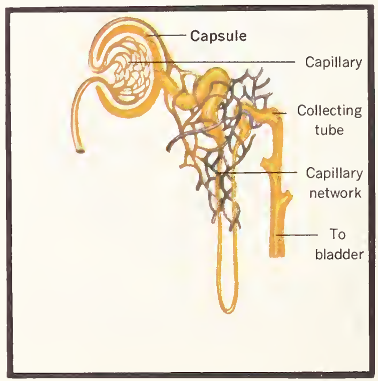
There are about two million filters in the kidneys. Every three minutes the whole five to six quarts of blood in your body pass through one of the kidneys.

Within the kidneys are about two million "filters." Each filter is a very small capsule leading into a coiled collecting tube. Water and other wastes pass out of the capillaries into the capsule. Some water and dissolved foods pass back into the blood as the fluid flows through the coiled tube. The rest empties into the bladder.

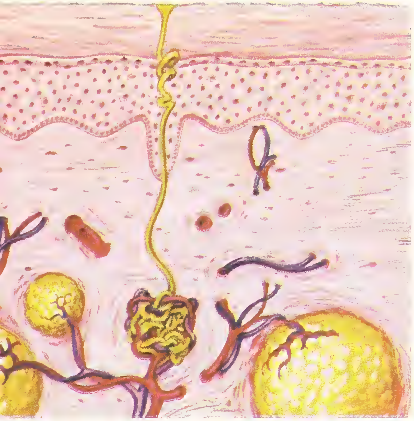
THE EXCRETORY SYSTEM



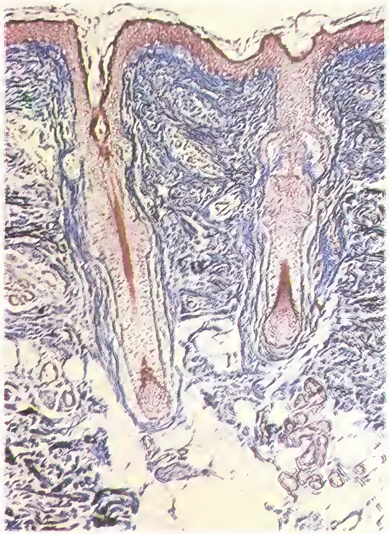




Closeup shows the relationship of blood to the collecting tubes inside a kidney.



These are the pores in the skin. Each pore is the opening of a sweat gland. A sweat gland is a tiny tube coiled up into a ball surrounded by capillaries. How do water and other wastes get to the surface of the skin?



The kidneys filter your blood. What is left is called **urine** (YOOR-in). Urine passes down into the long tubes leading to the bladder. It stays there until you **urinate.**

Your kidneys keep the amount of salt in your blood about the same all the time. They control the amounts of sugar and water, also. Your kidneys help you to stay alive and healthy.

Your skin also helps you get rid of wastes. When you run or jump, you sweat. You also sweat on very hot days. But did you know that you are always sweating a little bit? Right now, as you read this book, you are sweating, or **perspiring** (per-SPYR-ing). Sweat, or **perspiration,** is mostly water with some salts dissolved in it. This is why sweat has a salty taste. Where does sweat come from?

Sweat glands are located in the under-layer (dermis) of your skin. These glands remove water and salts from the blood and pour them in the form of sweat through tiny openings in your skin. You can see these openings if you look with a magnifying glass.

- *What happens when you perspire?*
- *Can you tell what happens when the skin is clogged by dirt or other substances?*
- *Why is regular washing so important?*
- *What does perspiring have to do with the body temperature?*

Try an experiment to show that perspiration creates a cooling effect on the body. Ask one pupil to dab a piece of cotton soaked in alcohol on another pupil's skin. The second pupil will report that his skin soon feels cooler. Repeat the experiment, but use cotton soaked in water. As the water dries from the skin, the skin feels cooler.

- *What does this experiment show about perspiration?*

TEACHING SUGGESTIONS
(pp. 96–97)

● LESSON: What parts of the body make movement possible?

Learnings to Be Developed: Muscles, bones, and joints make movement possible.

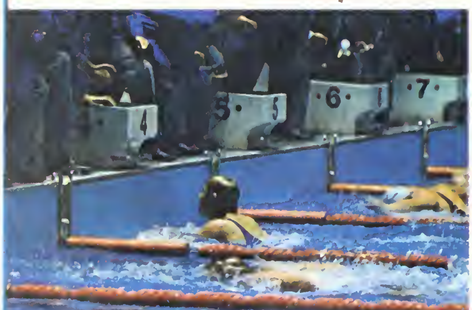
Developing the Lesson: Have the class look at the pictures on page 96.

- *What muscles are being used in each situation?*
- *What muscles are you using as you look at these pictures?* (Eye, hands, fingers.)
- *Can you move your muscles whenever you want to?* (Let pupils try to wiggle their ears.)

Have the class study the top picture on page 97. The muscle which works in bending the arm is the *biceps,* located on the upper part of the arm. The muscle which works in straightening the arm is the *triceps,* located on the under side of the arm.

- *When does a muscle do work?*

Perhaps one pupil has saved a cardboard Halloween skeleton. This is a good model, because it shows movable joints. Or use a diagram of the human skeleton. Let pupils take turns demonstrating with the skeleton.



Your Muscles and Bones

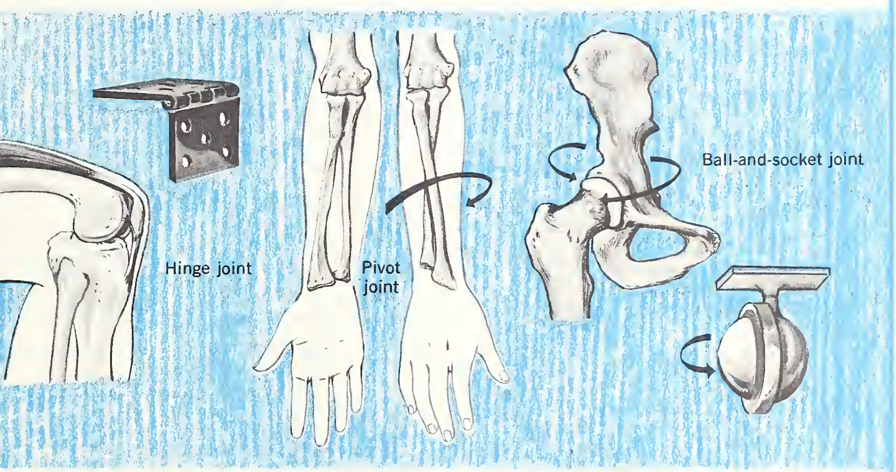
The people in the pictures at the left could not have done these things without **bones** and **muscles.** Every move that you make requires the smooth working of bones and muscles. There are over 800 muscles and 206 bones in your body.

Muscles do work only when they get shorter. When a muscle gets shorter, it is said to contract. When a muscle contracts, it pulls or turns some part of the body. You can feel this happen. Place one hand around the upper part of your other arm. Bend that arm. Do you feel a bulge? The muscle is getting shorter. Straighten your arm. The muscle on the outside of your arm contracts. One muscle bends your arm, and another one straightens it. Muscles can do work only when they contract.

Most of the muscles you use in moving are fastened to bones. Your bones make up the framework that supports your body. Some of your bones also protect vital organs, such as the brain, heart, and lungs.

You can turn your head from side to side. You can bend down to touch your toes. You can bring your knee up to your chest. You can move in these and other ways because your skeleton is **jointed** (JOYNT-id).

Which muscles are doing work in each of these pictures? How can you tell?



- *What bones protect the brain?*
- *What bones protect the lungs and heart?*
- *What parts of the skelton connect bones together?*

Let the class study the bottom picture on page 97. Let them identify each kind of joint on the skeleton.

ADDITIONAL ACTIVITIES:

Obtain a lamb shank from a local butcher. Carefully remove the outer layers of fat and connective tissue. Expose the underlying muscles and tendons. Tendons consist of elastic tissue that connects muscle and bone. The ball-and-socket motion of the knee joint can be demonstrated by pulling on the long upper tendon. The large muscle contracts. Now pull on the tendons of nearby muscles. This will cause expansion of the large muscle and straightening of leg.

Obtain several chicken feet. After removing the skin, let the class point to exposed tendons. Pulling on the long tendons will cause contraction and expansion of individual muscles in the foot. This is how muscles in our hands and feet work.

TEACHING SUGGESTIONS
(pp. 98–99)

Background: The answers to *Using What You Have Learned* are:

1. Individual answers.

2. The evidence suggests that there is a relationship between size and rate of heartbeat. The rate of heartbeat increases as the mammal's size decreases.

3. The results of this experiment should lead to a class discussion on how heartbeat is affected by exercise and temperature.

4. Starch does not dissolve in water; it remains cloudy. Sugar dissolves in water and thus can diffuse through a membrane. Starch must be changed to sugar so that the body can use it.

5. Starch will not go through the paper funnel. The iodine test will be negative. Test for sugar by tasting, or use Benedict's solution.

What is a joint? Have you ever seen a puppet dance and bow? When its strings are pulled, a puppet can move in certain ways because it is jointed. It has joints at its elbows and knees, and its neck, and at its wrists and ankles. The joint is where the end of one piece of wood meets the end of another piece.

Your joints are places where the end of one bone meets the end of one or more other bones. Look at the picture on page 97. The elbow joint is where the end of the bone of your upper arm meets the ends of the two bones in your forearm. You have joints in your hands, legs, feet, backbone, and lower jaw. You have four kinds of joints: hinge joints, pivot joints, gliding joints, and ball-and-socket joints. The picture shows how three kinds of joints work.

Using What You Have Learned

1. As you grow up, your heart beats more slowly. A newborn baby's heart beats about 140 times a minute. By the time he is three years old, it has slowed down to about 120 beats a minute. Between the ages of five and twelve, it beats about 100 times a minute. Between thirteen and twenty-one, it beats about 90 times a minute. After twenty-one, it beats about 75 times a minute.

Knowing this, would you expect the rate of your heartbeat to be much different from that of your parents'? Each member of the class might find out these rates and compare his findings with those of his classmates.

2. Here are the heartbeats of several adult mammals:

Elephant: 25 beats a minute
Horse: 50 beats a minute
Dog: 100 beats a minute
Rabbit: 150 beats a minute

From this evidence, what could you hypothesize about the sizes of mammals and the rates at which their hearts beat?

3. Does your heart beat faster:
when you are standing up or lying down?
when you are in a warm room or outside where it is cold?
before or after you eat a meal?

Plan an experiment to compare your results with those of other members of your class.

4. Put a teaspoon of cornstarch in one glass of water. Put a teaspoon of sugar in another glass of water. Stir each with a spoon. Why is the starch water cloudy and the sugar water clear? Has the starch dissolved? Let the glasses stand for one day. What happens to the starch? How does this help to explain why starch has to be changed so the body can use it?

5. Stir the starch and water again until the starch is mixed with the water. Take a teaspoon of starch-water mixture and put a drop of iodine into it. The mixture turns blue. This is a test for starch. It shows that there is starch in the mixture.

Now make a funnel with a piece of paper towel and put it in an empty glass. Stir the glass of starch and water again. Slowly pour some of the starch water into the paper funnel. You may have to hold the sides of the funnel to keep it from dropping to the bottom of the glass. You will see the water drip from the paper funnel into the empty glass. This is something like the way water goes through the lining of the small intestine. After the water has run through, look at the inside of the paper funnel. You will see that some starch is left inside. Did any go through with the water? You can tell by testing the water with a drop of iodine.

Now you can try the sugar water to see if the sugar will go through a paper funnel with the water.

How can you tell if there is sugar in the water before you pour it into the funnel? How can you tell if there is sugar in the water after it goes through the paper funnel?

○ **ADDITIONAL ACTIVITIES:**

Construct a simple apparatus to demonstrate the valve action of the heart.

Make a wire model representing arteries, veins, capillaries.

Study the blood cells of a frog or salamander.

Study diffusion and digestion in paramecia.

Dissect a fish or frog to show the digestive tract.

Prepare a sealed, balanced aquarium using snails, small fish, and algae.

Study the effect of exercise on rates of heartbeat and breathing.

Compare rates of production of carbon dioxide by yeast cells at various temperatures.

Study the action of contractile vacuoles in paramecia, which are believed to have an excretory function.

Slice a cow or hog kidney to show the cortex, which contains tubules and capillaries, and the inner cavity with the funnel leading to the ureter.

Macerate muscle tissue of a frog. Compare the appearance of voluntary and involuntary muscle tissue under the microscope.

TEACHING SUGGESTIONS
(pp. 100–105)

LESSON: How do we adjust to change?

Background: We know that the physical environment changes; conditions are not constant for even a short period. In 24 hours the succession of night and day changes the amount of heat and light on the earth's surface. All organisms must make appropriate responses to changes in the environment if they are to survive. Even one-celled animals respond to the environment. Human beings respond in a variety of ways—changing the environment itself is a response only man can make. In order to respond appropriately, an organism must get correct information about changes that affect it. The human body gets such information through its *nervous system* and related structures of *sense organs*, *muscles*, and *glands*.

Learnings to Be Developed:

All organisms respond to certain changes in the environment.

Man learns about changes in the environment through his sense organs and nervous system.

Developing the Lesson: The answers to many of the motivating questions in earlier lessons of this

How does this help to explain why starch must be changed to sugar before starch can be used in the body?

6. Make a model of your lungs. You will need a lamp chimney, a one-holed rubber stopper, two plastic feeding tubes, two rubber balloons, and a piece of rubber sheeting. Attach the balloons with rubber bands to the ends of the feeding tubes. Without further instructions try to make a model that shows how you breathe.

Adjusting to Changes

Even when you are sitting still, your body is active. Watch a friend as he reads. Does he lean first on one elbow and then on the other? Does he cross first one leg and then the other? Does he slump in his seat and then stretch? All these movements help to rest muscles when they get tired. Your body regulates itself and adjusts to changes without your thinking about it.

Your muscles are not the only parts of your body that must adjust in this way. When you run very fast, your body needs more oxygen. You breathe more quickly to provide your body with the additional oxygen. You do not think, "I must breathe harder to get more oxygen." Your body makes this adjustment automatically.

You perspire more on a hot day than on a cold day. Perspiring helps cool your skin. This is one way you adjust to changes in outside temperature.

When you go into a room where there is little light, you cannot see very well at first. But soon the pupils of your eyes enlarge to let in more light, and you can see better. Your body adjusts to changes in the amount of light.

All Living Things Adjust to Change

You remember that the body temperature of the turtle, a cold-blooded animal, changes with the temperature outside its body. When the outside temperature is high, its body temperature is high. It becomes more active. When the outside temperature is low, its body temperature

is low. It becomes less active. The turtle's body has adjusted to an outside change in temperature. Some warm-blooded animals, like bears, adjust to cold weather by hibernating.

All living things have ways of adjusting to changes.

Put a plant in a window. Make a drawing of the plant. Perhaps you can even take a photograph. Look at the plant again in a week. Observe its leaves and stems carefully. In what direction are they facing now? Compare the direction with that in your picture.

Like plants and other animals, humans adjust to many changes both inside and outside themselves. But human beings adjust to many changes better than any other living things do. For example, when winter comes, a fox grows heavier fur and finds a hole or a hollow log in which to live. A frog buries itself in the mud at the bottom of a pond until spring comes. Many birds fly away to a warmer place.

But human beings can build houses to live in. They can heat their houses. They can make clothing to wear. Human beings can adjust to changes by changing the world about them. They can do this because the human **nervous system** is more complicated than that of any of the other animals. Let's see how your nervous system helps you adjust to changes and helps you change the world about you.

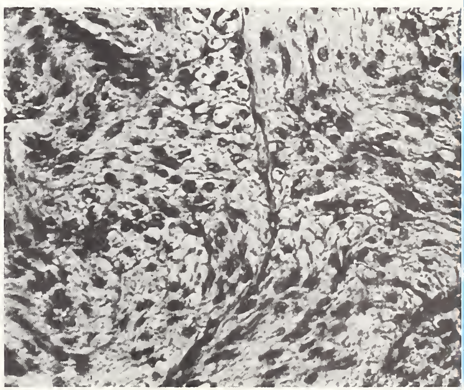
Your Nerves

Wiggle your thumb. Can you explain what made it wiggle? Did you tell it to wiggle?

For any part of your body to move, a message must travel from one part of your body to another. These messages are carried over thin thread-like fibers called **nerves.** The nerves are made of special cells, called **nerve cells.**

You know about some kinds of messages. When you speak to a friend on the telephone, your message travels by

These are nerve cells. Do they look different from other cells you have seen? How?



unit implied the body's ability to adjust to change. The first lesson pointed out how scientists studied the effects of the environment on our bodies. Repeat some of these questions (pp. 78–79) or those in subsequent lessons. This will establish the concept of adjusting to change and will serve as a review of what the class already knows.

- *Even simple organisms respond to light, water, touch, gravity, temperature, chemicals.*
- *Have you observed any behavior in plants or animals that suggests they are adjusting to the environment?*

Bring out the effects of changing seasons, day and night, rain and sunlight. There are several demonstrations that the class can perform to see different responses in simple organisms. These demonstrations are listed under Additional Activities, pages 104–105.

- *Does it feel warmer or colder in the classroom than outside?*
- *How do you know when it's time for the next class? Do you listen for the bell or do you look at the clock?*

Review these senses: *seeing* (vision), *hearing* (audition), *touch, taste, smell.* List these on the chalkboard.

* *Which organs or structures of the body are involved with each sense?*

Now introduce the terms *nerves* and *nerve cells. Sensory nerves* are those nerves that receive impulses from the sense organs. These impulses are carried along as *nerve messages*. The class should be led to appreciate the analogy in the text comparing a nerve message to an electrical message. Let the class study the pictures on pages 101 and 103. Let them also refer to the picture on page 37 showing nerve cells.

* *How do these nerve cells compare with other cells you have seen in this book? What is their shape?*

Point out that nerves are long, thin bundles of nerve cell tissue. Nerve cells are the longest cells in the body. Some are 3 feet long—from finger tip to spine. But they cannot be seen without a microscope.

* *The picture on page 103 shows different kinds of nerves. What message does each carry?*

Review the different kinds of messages that are picked up in different nerve endings in the skin. Sensory nerves in the skin discriminate among sensations of heat and cold, light touch, deep

electricity at a speed of 186,000 miles a second. At that speed, it could travel around the world more than seven times in just one second!

When you shout to a friend at the other end of the schoolyard, your message travels at a speed of more than 1,100 feet a second. At that speed, it would take it about a day and a half to travel around the world just once!

A nerve message is different from the electrical message sent over the telephone. A nerve message is also different from the sound message when you speak or shout. Here are two ways in which the nerve message is different:

1. A nerve message travels along living cells.
2. A nerve message can travel in only one direction in any single nerve cell. (An electrical message can travel in either direction along a wire.)

In your body, a nerve message travels at a speed of about 300 feet a second. If you are 5 feet tall, a nerve message can travel from your brain to your toes and back again more than 30 times in a single second! Nerve messages travel so fast that you can move a finger in the same second in which you think of wanting to move it.

Different Kinds of Nerves

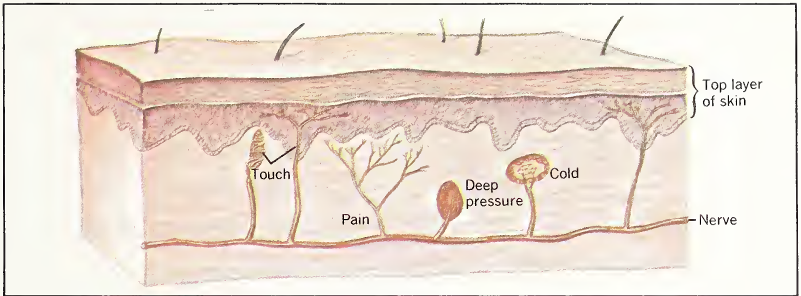
If you touch your finger with a pencil point, you feel it, of course. You feel it because a nerve carries the message of touch to your brain. You know that a pointed object touched you even though you did not see it.

Try this. Close your eyes and run your finger tips lightly over the desk top. You can feel every little bump along the desk, even the grains of dust and other particles on the desk top. Why?

Now run the back of your hand lightly over the desk top. You will not feel nearly as many bumps and specks of dirt with the back of your hand as you did with your finger tips.

You may have noticed something strange when you tried this comparison. With your finger tips, you felt many small bumps and particles. But you did not especially feel coldness from the desk top. With the back of your hand, you did not feel bumps and specks of dirt, but you did feel cold spots. Try it again if you did not feel these cold spots with the back of your hand the first time.

Try the same comparison with a piece of ice. Touch your finger tips to the ice. Then lightly run the back of your hand over the ice. What difference do you feel? What does this comparison tell you about nerves in your hand?



This section of skin shows the many kinds of nerves that are found in the skin.

You may have guessed that there are several kinds of nerves in your skin. Some of them carry the message of touch. Some of them carry the message of cold. Other nerves in your skin carry messages of heat, and still others carry messages of pain. Each nerve in your skin carries only one type of message.

But you do not find out about things through your skin alone. You have other senses besides your sense of touch. There are nerves that carry messages from your eyes to your brain. Other nerves carry messages from your ears to your brain. You taste and smell things because of nerve messages.

Have you ever received a very sharp blow on the head? When this happens, you sometimes "see stars." You "see stars" because certain nerves in your head have been made active by the blow. Since these nerves carry only the message of light, you see "stars."

The Sense of Taste

Nerves that end in your tongue help you to taste things. And just as you have different kinds of nerves in your skin, you also have different kinds of nerves in your tongue. One kind carries the message of salty taste. Another kind helps you to taste sweet things. Others carry taste messages of bitter things and sour things. And, like your skin, different parts of your tongue have different kinds of nerve endings. For some kinds of taste, there are more nerve endings near the tip of your tongue. For other kinds of taste, there are more nerve endings at the back or along the sides. Now try the experiment on the next page.

pressure, and pain. The picture shows the nerve branchings that carry messages about different sensations. Let the class experiment with their own sense of touch.

- *Do different parts of the skin have nerve endings that are sensitive to different sensations?*

Blindfold a few pupils. Let other members of the class apply hot, cold, rough, and smooth objects to the arms, hands, legs, and backs of the blindfolded subjects. Apply various amounts of pressure.

- *Where did you feel each sensation?*

Now insert the tops of two pins close together in a cork so that the points extend outward. Gently bring the pin points to the surface of the skin of the fingertips and different parts of the hands, arms, and backs of the blindfolded pupils.

- *Do you feel one point or two separate points? Where?*

Only the finger tips will discriminate between separate points. This is because touch *receptors* (nerve endings) are much more numerous and closer together in the finger tips.

- *Do different parts of the tongue have different nerve endings that discriminate among salty, sweet, sour, and bitter tastes?*

Let the class find out about their sense of taste by doing the experiment on page 104. The tip of the tongue has the most nerve endings for each taste. You should rinse out your mouth and dry your tongue between each test so that there is no residue of the substance just tested.

Have the class look at the pictures on page 105. The picture at the left shows a cross section of the nasal passage.

- *Where are the nerve endings shown?* (High up in the nose.)

ADDITIONAL ACTIVITIES:

The class may try some of these demonstrations to see how various organisms respond to changes in the environment.

Response to light: Put insects (moths or fruit flies) in a tall glass jar. Shine a light (flashlight) at one end of the jar, or bring the jar near a sunny window. Elicit the conclusion that the insects are attracted toward light. (This response is a *phototropism.*) To be sure that this is not a response to gravity, lay the jar on its side and repeat the experiment.

EXPERIMENT

Where Are the Nerve Endings in Your Tongue?

What You Will Need

salt	mirror
lemon	small, clean brush
sugar	5 cups of water
Epsom salts	clean handkerchief

How You Can Find Out

1. Dissolve some salt in one cup of water.
2. Squeeze some lemon juice into another cup.
3. Dissolve some sugar in another cup of water.
4. Dissolve Epsom salts in another cup of water.
5. Then dry your tongue with the clean handkerchief.
6. Dip the clean brush into one of these solutions and then touch the tip of the brush lightly to different places on your tongue. Repeat for each solution. Between each taste, take a drink of fresh water and dry your tongue with the handkerchief.
7. Record where you taste each substance best. The mirror will help you see the exact spot you are touching.

Questions to Think About

1. Why should you dry your tongue between each taste?
2. Which part of your tongue has the most nerve endings for each taste?
3. Can you now draw a picture to show where the four different kinds of nerve endings are located along your tongue?

The Sense of Smell

You have probably noticed that when you have a cold, you do not enjoy eating. That is because you need more than the nerve endings in your tongue to get the full flavor of anything you eat. Each food has a smell as well as a taste. The message from your tongue and the message of smell from your nose combine to give each food its own particular flavor. A bad cold prevents you from smelling things as well as you usually can.

The nerve endings for smell are high in your nose. Usually, only a small part of the air you breathe passes over these nerve endings. If you really want to smell something well, you must get the air up to the nerve endings high in your nose passage.

Have you ever noticed how a dog sniffs at something when he wants to smell it better? A dog's nerve endings for smell are also high in the nose. He sniffs the air up to these nerve endings to smell things better.

Here is a comparison you can make to show how bringing the air high into your nose helps you smell things better. Take an orange. Nick the skin of the orange to release some of the odor and hold it near your nose. First, breathe as you usually do. See how much you smell the orange. Then take a deep breath. Compare the odor of the orange when you breathe as usual with its odor when you take the deep breath.

Here is something else you can try with the same orange. Hold the nicked

Response to water: Wet one piece of heavy blotting paper in water. Keep another piece dry. Place the two side by side in a Petri dish. Leave a space between them, and place three lima beans in different positions in the space left. Cover the dish and set aside for a few days. Elicit the conclusion that rootlets grow toward the wet blotter. (This is called a *hydrotropism.*)

Response to gravity: Lay a flower pot containing a growing plant on its side. After several days observe the upward growth of the stem and leaves. (This is a *negative geotropism,* moving away from the pull of gravity.)

Response to chemicals: Put a drop of paramecium culture on a glass slide. Cover it gently with a cover glass. Put a drop of weak vinegar or acetic acid at one edge of the cover glass. Watch the reaction of the paramecia. Elicit the conclusion that they are attracted toward the solution. (This response is a *chemotropism.*) You might also test with salt, sugar, and other chemicals.

Response to touch: Obtain a plant (mimosa) with leaves sensitive to touch. Touch its leaflets with a pencil. The closing of its leaflets is a *thigmotropism.*

TEACHING SUGGESTIONS
(pp. 106–108)

LESSON: How does the nervous system interpret information from the environment?

Background: We have seen how simple organisms respond to stimulation from the environment. But one-celled animals, such as ameba and paramecia, do not have a nervous system. Some many-celled organisms, like the sponge, do not have nervous systems either. The beginning of a nervous system is found in the hydra (a fresh-water animal) and the jellyfish. The hydra has a nerve net spread throughout its body. Messages travel in all directions. Such an animal shows poor coordination. In higher animals and in man messages travel in one direction. The *brain* coordinates and selects the messages; the *spinal cord* routes all incoming and outgoing messages along proper channels. Incoming messages travel to the brain along *sensory nerves*. Outgoing messages travel from the brain along *motor nerves* to parts of the body where actions are carried out. There are 12 pairs of nerves that go to the brain and 31 pairs that go to the spinal cord. The brain and spinal cord together make up the *central nervous system*. The central sys-

orange to your nose and smell it. The odor will seem strong. Keep the orange there for several minutes. After a while, you will no longer smell the orange as strongly as you did at first. Is this because the odor from the orange is all gone? Or is it because your nerves of smell do not carry the message as well as they did when you first smelled the orange? Make another nick in the skin to release fresh odors to find out.

The nerves that carry the message of smell get "tired" after carrying one odor for a long time. They no longer carry the message of that smell as well as they did at first. Do you remember coming into your house just before mealtime and smelling food cooking? Then, after a while, you no longer noticed the smell. Your nerves for smell had become "tired" of that particular odor.

Your Other Set of Nerves

So far, you have learned about nerves that carry messages of touch, taste, and smell to your brain. These nerves are sometimes called **sensory nerves** (SEN-ser-ee). But we still have not found out why your thumb wiggled. How did it get the message that made it wiggle?

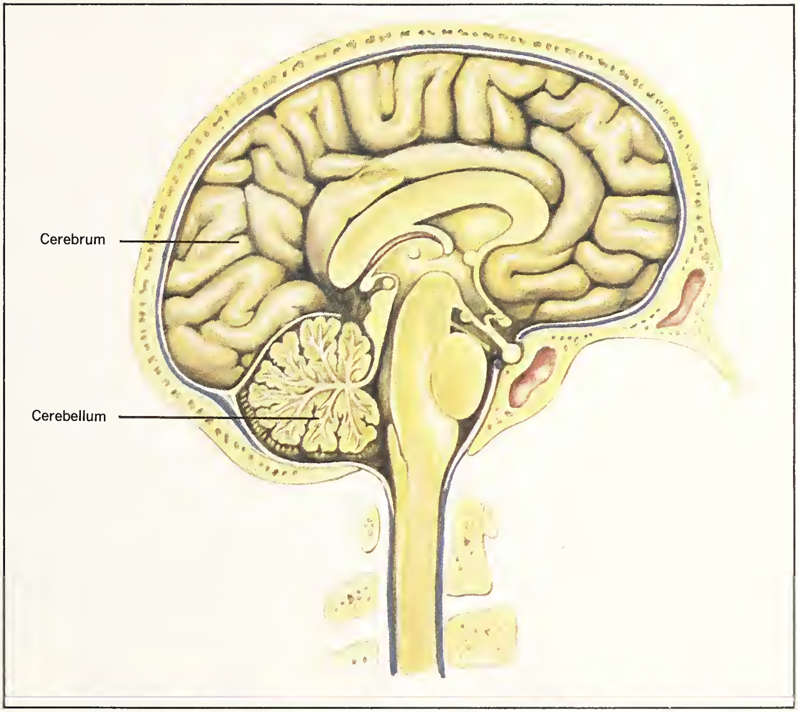
To move any part of your body, you must use two sets of nerves. As you have already learned, one set carries messages from your senses to your brain. The other set carries messages from your brain to your muscles.

Let's see what happened in your body to make your thumb wiggle. With your eyes, you read, "Wiggle your thumb." In your eyes, the message was changed into nerve impulses. This message traveled along nerves from your eyes to your brain. If you then decided to wiggle your thumb, a message had to travel along other nerves from your brain to the muscles in your thumb.

The nerves that carry messages away from the brain are sometimes called **motor nerves.** Before you kick a football, or pick up your books, or write your spelling words, or do any other activity, messages must travel along the motor nerves to your muscles.

Messages are sent to the brain by the sensory nerves from all parts of the body. Orders come from the brain by way of the motor nerves, making the various body parts do certain things.

The sensory and motor nerves are part of your nervous system. Your brain and **spinal cord** (SPY-n'l) are the center of your nervous system. They make up your *central nervous system*. The "lines of communication" are the nerves —12 pairs of nerves go to the brain and 31 pairs go to the spinal cord.



A model would be helpful here.

Your Brain

Each part of your brain receives messages from a different part of your body. A message from your right thumb to your brain starts in the nerve endings in your right thumb, passes to the nerves in your spinal cord, and travels from there to the left side of your brain.

All messages from the right side of your body go to the left side of your brain. And all messages from the left side of your body go to the right side of your brain.

Notice the **cerebellum** (sehr-uh-BEL-um) in the picture. When a person's cerebellum does not work as it should,

tem interprets the information coming from our sense organs, skin, and muscles involved in voluntary activity. It also controls such conscious behavior as learning, problem-solving, memory, and judgment. It controls the processes associated with the sensory organs, such as seeing, hearing, talking, and conscious motor activity.

Learnings to Be Developed:

The brain and spinal cord make up the central nervous system.

The central nervous system controls all "higher" activities.

Different parts of the brain control different activities.

Developing the Lesson: Have the class study the diagram on page 107.

- *Which part of the brain is the largest?*

Review the functions of the cerebellum and the cerebrum. The cerebellum controls balance and coordination of voluntary muscles — those involved in moving body parts for swimming, walking, jumping, etc. The cerebrum controls sensory and motor processes —those involved in seeing, hearing, talking, and certain muscular activity. The cerebrum also controls conscious thought and be-

havior—learning, problem solving, memory, and judgment.

- *Compare the activities of the cerebrum and the cerebellum. Which activities are more complex?*
- *Can you now explain why the cerebrum is the largest part of the brain?*

Scientists have learned a great deal by studying the brain.

Review the text on pages 108–109 and the picture on page 108.

- *Do different parts of the cerebrum control different activities?*
- *What are scientists doing to find this out?*
- *In what part of the brain does personality seem to be controlled?*
- *What kind of experiments are scientists making on the brains of monkeys?*
- *What do they hope to find out?*
- *In what way did the monkeys Dave and Larry change after the experiment?*
- *Why was the frog still able to carry on most activities even though its cerebrum was removed?*

he can hardly walk. All his movements are jerky. The cerebellum automatically takes care of co-ordination. By co-ordination we mean smooth action of muscles.

Look at the **cerebrum** (SEHR-uh-brum) in the picture of the brain. The cerebrum is the part of the brain concerned with thinking. It is in the cerebrum that messages of sight, sound, taste, smell, and touch are received and decisions as to what the messages mean are made.

Scientists are trying to find out more about the cerebrum. They are trying to map the cerebrum; that is, they are trying to find out which parts of the cerebrum control various activities. For example, they have located the sections of the cerebrum that control sight, speech, and some muscles. Further research will help to make the maps more detailed.

Scientists are also trying to discover how changes in the brain affect the way one behaves. They know that personality seems to be controlled largely in the front section of the brain. It is in this part that mental activities like worrying or being afraid originate.

Scientists have found that it is possible to change a monkey's way of behaving by operating on this front section. First, they observed a group of monkeys and made notes about how they behaved.

Look at the pictures on this page and you will see what the scientists observed.

Dave was the Number 1 monkey and boss of the group. The other monkeys

Dave—the boss | Zeke—the fighter | Herby—quiet | Shorty—attacks only Larry | Larry—a coward

Zeke—new boss | Herby—still quiet | Shorty—still attacks Larry | Larry—now attacks Dave | Dave—now a coward

were afraid of him. Larry was the most timid monkey. He was the last in the group.

Then scientists operated on Dave's cerebrum. Notice where Dave is in the group now. He is no longer the Number 1 monkey; he has moved to the very bottom of the group. Even Larry, who was the most scared of all the monkeys in the first set of pictures, can now boss Dave around. Larry did not have an operation, but he changed when he had someone to pick on.

In another experiment, scientists removed most of the cerebrum of a frog. The frog still hopped around. It digested food. In fact, the frog was able to carry on almost all its activities and lived for several weeks.

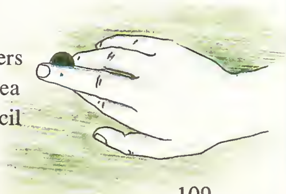
Experiments such as these help scientists learn about the brain and the nervous system. There are still many things to be discovered about the brain. As scientists learn more, they hope to be able to help people with various kinds of brain injuries.

Using What You Have Learned

1. Try to find out where different kinds of nerve endings are located on your skin. With a sharp toothpick, lightly tap sections of skin on your arm. When you tap some places you will not feel very much. When you tap other places, you will feel a slight pain.

2. Are there more nerve endings for the message of cold on the underside of your wrist than on the top? How can you find out? (Have you ever seen a mother test the temperature of milk before giving it to her baby by sprinkling some of the milk on her wrist?)

3. Get a small pea. Hold it between your crossed fingers as shown in the drawing. Close your eyes and move the pea slightly. It feels like two peas instead of one. Slide a pencil between your crossed fingers and you will feel two pencils.



TEACHING SUGGESTIONS
(pp. 109–111)

Background: Pavlov's first work was with the physiology of digestion—in particular, the nervous mechanisms that controlled the flow of gastric juices in the stomach. In his experiments, he proved that stimulation of nerves in the mouth caused the brain to stimulate the flow of gastric juices in the stomach. Fundamentally, Pavlov showed the importance of the autonomic nervous system in regulating the functioning of the body's systems.

Many people are under the impression that all Pavlov did was prove that a dog's mouth could be made to salivate whenever a bell rang or a light flashed. The true importance of Pavlov's work with conditioned reflexes was to show the process by which the brain learned new things and learned how to cope with the external environment.

Developing the Lesson:

- *What have scientists done to follow up the work of Pavlov?*
- *Do any of your pets act like Pavlov's dog? What happens when they hear the refrigerator being opened? What happens when you tap the sides of the goldfish bowl?*

The story of Pavlov's work is a good example of how continued experimentation leads to important discoveries. His work on conditioning opened a fresh area for study of learning and behavior. Scientists have since conducted many experiments on conditioning. Review the concepts of reflex and conditioning.

Tell the class you would like to try an experiment. Direct them to put a dash on a line every time you say, "Write." Tap the desk with a ruler every time you say, "Write." Do this 15–20 times. Then stop saying, "Write," but continue tapping at the same rate as before. See how many pupils continue writing a dash. This demonstrates a temporary conditioned response.

- *What reasons can you give for this behavior?*

Point out that an association was made in their minds between tapping and the command to write. Finally tapping was identified with the oral command.

- *What other examples of conditioned learning have you observed?*
- *Can animals be trained by conditioning them?*

Discuss how reward and punishment may result in conditioning.

Here is the reason. Ordinarily, the two parts of your skin touching the pea do not touch the same object at the same time. They do not usually carry the same message at the same time. When you cross your fingers, these two parts of your skin do touch the same object at the same time. But it still seems to you as if the messages are coming from separate objects—just as they usually do from these two places. Therefore, you have the illusion that there are two peas.

PATHFINDERS IN SCIENCE

Ivan Petrovich Pavlov

(1849–1936) Russia

Ivan Pavlov was honored in a way that very few scientists are. His work was known throughout the world during his lifetime.

Pavlov had a brilliant mind and a great memory. He seemed to have endless energy and enthusiasm for work. Even at the age of 80, he had a vast enthusiasm, which he communicated to all those around him, for scientific investigation. He was the moving spirit for most of his laboratory's projects. When an experiment was successfully completed, he would dance with joy. It is said that his laboratory was run like a town meeting: on Wednesdays, the scientists gathered to discuss and argue their problems. Pavlov would fight very hard for his ideas. However, when he was in error he was quick to admit it.

Much of Pavlov's early work was done in a laboratory that was a small wooden building—not much more than a shed. The money for his projects came mostly from his own very small salary. He had no regular assistants. Yet, because of his fine mind, energy, and self-sacrifice, he was

4. Whether something feels hot or cold to you involves making a comparison. Try this. Get three bowls. Put warm water that is about 90° F. in the first bowl. Put water that is about 60° F. in a second bowl. In the third bowl, put cold water that is about 35° F. Put one hand in the first bowl and your other hand in the third bowl. Keep them there for thirty seconds. Then put both hands in the second bowl. How does the water in this middle bowl feel to each hand?

awarded the Nobel Prize in 1904 for his research on the digestive system.

One of Pavlov's discoveries was that the nervous system plays a vital part in digestion. In the stomach are juices that help to break down food and prepare it for use by the body. Pavlov showed that the flow of these juices is controlled by nerves that extend from the head through the neck. When you chew food, these nerves are stimulated. The juices start flowing in the stomach even before the food arrives there. The flowing of the juices is an automatic reaction, called a "reflex."

Today we remember Pavlov more for his work on learning than for his work on digestion. While studying reflexes that aid digestion in the dog, Pavlov noticed an interesting thing about saliva forming in the mouth of the dog. You know that, when you have food in your mouth, the saliva flows automatically and mixes with the food. But during his experiments with dogs, Pavlov noticed that saliva flowed *before* the dog had food in its mouth; it started flowing when the dog saw food! Pavlov reasoned that the animal must have *learned* to react to the sight of food as he reacted to the food itself. Pavlov called this kind of learning **conditioning.**

Pavlov experimented to find out how conditioning takes place. In one experiment, a dog was placed in a room by itself, and a light was turned on. No saliva flowed. Then the dog was given meat, and saliva, of course, began to flow. A few more times, the light was turned on and then the meat was presented. After several trials, the dog's saliva began to flow as soon as the light was turned on, before the food was presented. The dog had been conditioned to associate the light with food.

Since Pavlov's time, scientists have done thousands of experiments on conditioning.

Try another experiment to show the strength of habit activities. Have children note how long it takes to write their full names three times in the usual manner. Then ask them to switch to the opposite hand to write their names three times.

- *How much longer does it take?*
- *Is writing a reflex action?*
- *How does a habit compare with a reflex? What are some advantages of habit formation?*

Follow-Up: Use prepared diagrams or make rough chalkboard drawings of the brains of fish, frog, and man. Compare the sizes of the cerebrum in all three. Note the growth in size and increase in the complexity of the human cerebrum.

○ **ADDITIONAL ACTIVITIES:**

You may wish to have pupils bring in reports on instincts in animals: nest building, spinning of webs, migration of birds and fish, the "dance" of the bees, courtship and mating behavior, social behavior of ants and bees (building colonies), the peculiar behavior of the digger wasp.

- *How do these behaviors differ from those shown by man?*

TEACHING SUGGESTIONS
(pp. 112–116)

● **LESSON:** How can we do things without thinking?

Background: We have seen how the central nervous system regulates conscious processes and interprets information from our senses. But the body is constantly adjusting to change, from outside and within itself, without our conscious awareness. The unconscious response and adjustment to change are accomplished by the *autonomic nervous system*. The actions it initiates are *reflexes*. The nerve cells regulating smooth muscle (e.g., those that control blood vessels), internal organs, and glands are grouped together as the autonomic nervous system. It derives its name from the fact that many of the activities it controls are autonomous or self-regulating activities—reflex activities such as digestion and circulation that go on even when you are asleep or unconscious.

The autonomic nervous system is closely integrated with the central nervous system via the *spinal cord* and *brain stem*. It includes all the nerve cells (or *neurons*) located outside the spinal cord and brain stem (except those involved with the sense organs). It also includes neurons located in

Doing Things Without Thinking

Imagine what your life would be like if you had to think about things such as keeping your body temperature unchanged, taking a breath, or making your heart beat! You would spend every moment thinking about these activities and would have no time left for anything else.

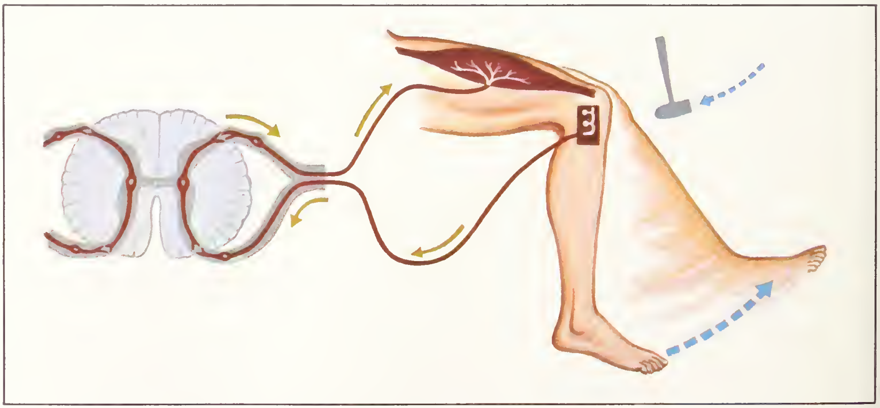
And what would happen if you did not remember to digest your food? What if you forgot to make your heart beat? What if you suddenly got tired of paying attention to breathing?

Your body does many important things that you never think about. Your cerebrum does not tell your body to do these things. How, then, does your body do these things?

You have already read about how your nerves control the movements of your arms and legs. Other nerves control your heartbeat and your digestion.

What happens when something irritating gets into your nose? What do you do if an object is coming toward your eye fast? Cross your legs and have someone tap you lightly on the crossed leg below the knee with the edge of his hand or a large stick. When your friend hits a certain spot below your

Can you tell what is happening in the diagram? What kind of nerve action is shown?



knee, your foot kicks out. You do not realize that your foot kicks out until you see it!

These activities do not depend at all on thinking. The nerves that control these activities do not go into the cerebrum. The messages that start these activities are picked up by nerve endings and travel to your spinal cord. The response is automatic. From your spinal cord, a message goes out that makes you sneeze, blink, or kick your foot.

The activity that follows from this kind of nerve message is called a **reflex** (REE-flekss). Sneezing is a reflex. So is blinking your eye when an object comes toward it. The kicking reflex is called the knee-jerk reflex. Doctors often test the knee-jerk reflex to see if the nervous system is normal.

Many reflexes keep your body operating smoothly. The eye-blinking reflex protects your eye from dust and flying objects. The sneezing reflex clears your nose of irritating objects.

Other reflexes are useful, too. If you accidentally touch a hot object, you pull your hand away immediately. You pull your hand away even before you are aware that you have touched something hot. The action is a reflex. Your body does it automatically. This reflex protects you from certain kinds of burns.

Body Temperature

You have learned that your body stays at about the same temperature at all times. This is something else your body does without your thinking about it. You can take your temperature at different times to see that this is true. Take it when you get up in the morning. Take it after playing. Take it on a warm day and on a very cold day. Take it just before you go to bed at night.

You will probably find that your body temperature does change during the day —but only slightly. You will find that your temperature is a bit higher immediately after you exercise. You may also find that other boys and girls have temperatures that are different from yours, even though all of you are healthy. But you will also discover that your temperature and your friends' temperatures seem to stay about the same—between 98° and 100° F.

One way your body keeps a steady temperature is by perspiring. You perspire more when it is warm. Nerve endings in your skin carry the message of heat to the temperature-control center in your nervous system. A message travels back to your skin and makes you perspire. Water is collected in your skin in thousands of sweat glands. It comes out of tiny openings in your skin

the spinal cord and brain stem that connect (via a conduction path) outward to the autonomic neurons. Nerve cells connecting the *sensory neurons* with the *motor neurons* are called *associative neurons*. The path taken by a reflex is from a sensory neuron to an associative neuron and on to a motor neuron, which activates a muscle or a gland. The path does not go to the brain.

Learnings to Be Developed:

The body does certain things automatically as reflex actions.

The autonomic nervous system controls these automatic activities.

Some activities of your body are influenced by the glands.

Developing the Lesson: Let the class refer to the diagram on page 107. Point out that the lower part of the brain, which connects with the spinal cord, is the *brain stem*. At the top of the brain stem is the *medulla* (*oblongata*). The medulla controls such reflex responses as breathing, swallowing, digestion, and heartbeat.

- *What activities does your body perform when you are asleep?*
- *In what ways do these activities differ from walking, talking, problem solving, and swimming?*

Have the class look at the picture on page 112. Point out that this is simple reflex. The messages that activate simple reflexes travel to the spinal cord, from which a message goes out that makes you kick.

- *What is the path taken by he reflex? Locate the sensory nerves, the motor nerves, and the associative (connecting) nerves.*
- *Which nerves activate the muscle in the leg?*

The body adjusts automatically to changes in temperature. Have the class read text pages 113–115.

- *Is the outside temperature the same during all seasons?*
- *What are two automatic activities that help to keep you cool?*
- *What automatic activity helps to keep you warm and your body temperature steady?*

Point out that evaporation of water from your body when you perspire removes some heat from the body. Heat is needed to make the water evaporate (change from liquid to vapor). The heat comes from your body.

Nerve messages affect one another in making the body adjust.

called pores. The moisture spreads over the surface of your body. How does this help to keep your body cool? Here is a way you can find out.

Take two dry cloths of the same size. Soak one in water and hang both cloths in the same place. Let them hang for five or ten minutes. Then feel them. Which cloth is cooler? Why?

When a wet cloth is wrapped around the bulb of one of two thermometers, the thermometer with the bulb wrapped in wet cloth will have a lower reading than the other. When water evaporates from an object, the object becomes cooler. Can you tell why?

The hotter it is, the more you perspire. The more water that evaporates from your skin, the cooler your body surface becomes. You can see that perspiring helps your body remain at about 98½° F. even on a hot day.

There is another way in which your body loses heat. Has your mother ever said, "Sit down for a while. You're getting overheated"? She can tell when you are very warm without actually touching you.

When you are warm, the blood vessels just under your skin automatically become larger. As they become larger and carry more blood, your face becomes flushed. But you get cooler when you become flushed. Much of your body heat is passed from your blood to your skin, because more blood is now at the surface of your body in the enlarged vessels. Your skin, in turn, gives off heat into the air, just as a stove or any other warm object does. Your body cools down. Perspiring and flushing are two automatic activities that help to keep your body at a steady temperature.

What happens when the air around you is cold? The blood vessels just beneath your skin automatically become smaller. They carry less blood. Not as much heat is passed from the inside of your body to the skin and from there into the air, because less blood is now at the surface of your body in the shrunken vessels. This action of your blood vessels helps keep heat inside your body on cold days. Nerves control this action.

Have you ever shivered so much that you could not talk? Shivering is still another activity that keeps your body at about the same temperature. When you are chilly, the muscles in your arms, legs, and face become tense. When your muscles become tense, they produce more heat. You become warmer. If you get very chilly, your muscles become so tense that you begin to shiver. Shivering produces still more heat and helps keep your body temperature steady.

Nerve Messages Affect One Another

When you feel dizzy, you feel as if you have lost your balance. The feeling of balance is controlled by a fluid inside the ear. When you are tilted, this fluid presses against certain nerves, and you feel off balance. You then try to right yourself.

People sometimes get motion sickness when they ride a roller coaster or an airplane. They are not used to being tilted or swayed. Yet, often when people get motion sickness, the fluid in their ears is in the normal position. The sickness is certainly there, but the nerve messages that cause the sickness are coming from somewhere other than the fluid in their ears.

Here is what happens. The person looks at the horizon, and it seems tilted or high or low. He is not used to seeing the horizon that way. Usually when he does see it that way, he feels off balance because he *is* off balance. But on the roller coaster or airplane he is not off balance. What nerve messages are traveling through his body?

Nerve messages from his eye carry the message of a tilted horizon. The message of a tilted horizon may make other nerves carry messages that cause motion sickness. But nerve messages from the ear carry the message that balance is all right. These messages from the ear reduce the motion-sickness messages.

Notice how the nerve messages act on one another. The messages from the ear partly cancel out the messages causing motion sickness.

The Glands

Some of the things that happen in your body are not controlled entirely by nerves. Some things happen because of certain chemicals in your body. These chemicals are produced in parts of your body called **glands.**

Have you ever been so scared or so excited that you did something you would not ordinarily be able to do? There is a newspaper story that tells about two women who were alone in a house when a fire started. The two frightened ladies lifted their piano and carried it outside. Later, it took five men to carry the piano back into the house! Everyone's body is able to produce a great amount of extra energy in an emergency.

When you are suddenly frightened, your heart beats faster and you breathe more rapidly. More sugar is released into your blood to give you extra energy. These changes prepare you to meet an emergency.

- *Have you ever looked down from a high place and felt dizzy only because you looked down?*

Sometimes we get information about the environment that we interpret incorrectly. Sometimes we think we are off balance, but our body really is not.

- *How does the body know it is not off balance when our eyes tell us it is?*

Balance is automatically controlled by a fluid inside the ear. You may feel off balance even though the fluid in the ears is in its normal position. The messages causing motion sickness come from the eye, which sees the environment in a strange way. Nerve messages from the eye and from the ear act on one another. The messages from the ear partly cancel out the messages causing motion sickness.

Have the class look at the diagram on page 116.

- *What chemicals do the glands shown release?*
- *What other glands have you studied that are not shown on this diagram?* (Salivary, sweat.)

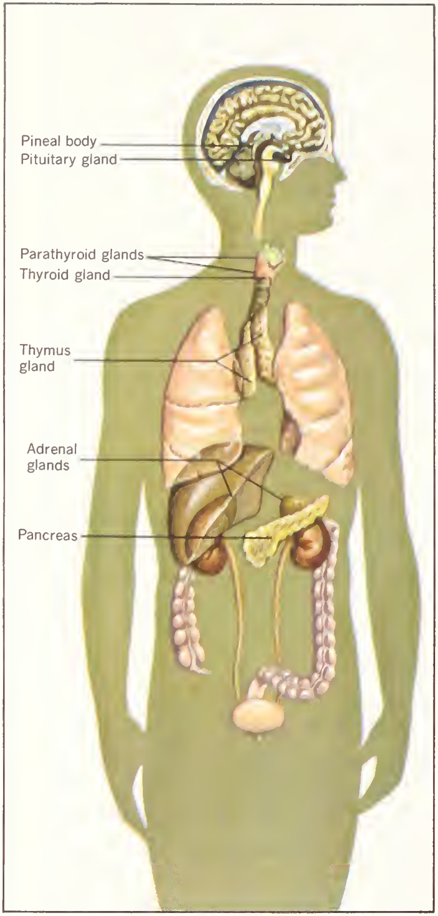
Point out that there are individuals with abnormally functioning glands. If the thyroid gland pro-

duces too much hormone (*thyroxin*), the rate of breathing and heartbeat is increased, and energy is used up very quickly. If the gland produces too little, these activities are slowed down and the person feels sluggish.

Ask the class to refer to p. 70, where they first learned about the pituitary gland as a growth regulator. If the pituitary gland produces too much or too little hormone, bone growth is abnormally large or abnormally small.

- *Have you ever seen a dwarf, a giant, or a bearded lady at the circus?*
- *What causes each of these abnormalities?*

The glands function automatically, all the time, and are regulated by the autonomic nervous system. But sometimes your glands need to work harder than usual—when you are frightened or angry. Then the central nervous system becomes involved. When your eyes or ears see or hear certain things, the brain instantly interprets these situations as frightening or angering. The brain relays these messages to the glands. The glands activate certain changes, which make your body produce extra energy to act in the situation.



The glands shown here all release their hormones directly into the bloodstream. Tell what each gland is responsible for in your body.

When you breathe faster, your body gets more oxygen. When your heart beats faster, the blood travels faster. It furnishes each cell with more food and oxygen so that it can produce more energy.

These automatic changes in your body are caused by a hormone released from your **adrenal glands** (ad-REE-n'l). The adrenal glands release their chemicals directly into the blood. You have two adrenal glands, one located on each kidney, just above the small of your back.

Other glands cause different automatic actions. As you may remember, the pituitary gland near your brain releases a hormone into your blood that controls how rapidly you grow. In fact, you cannot grow without the chemical from this gland. The parathyroid glands in your neck control the way your body uses the mineral calcium. The thyroid gland in your neck controls how rapidly your body uses up energy. All the various glands of your body do their work by releasing special hormones into your blood.

You have seen that you do certain things without thinking. You can do certain things without thinking because your nerves and your glands work to keep your body running smoothly.

Using What You Have Learned

1. You can feel the cooling effect of evaporation on your skin by putting a few drops of water on your wrist. Alcohol evaporates faster than water. Would evaporating alcohol make your skin feel even cooler than evaporating water? What experiment can you plan to find out? How can you be certain that the alcohol and the water are the same temperature before you start the experiment?

2. Why is it hard for you to keep cool on a muggy day?

3. Why do football coaches sometimes tell their players to "get mad"?

4. Why is it uncomfortable for your eyes when someone suddenly turns on a bright light in a dark room?

5. Tell how your reflexes have helped you in what might have been a dangerous situation.

TEACHING SUGGESTIONS
(p. 117)

Background: The answers to *Using What You Have Learned* are:

1. Yes. Alcohol would make your skin cooler than evaporating water because alcohol evaporates faster. Dab some tap water on the back of one hand of a pupil. Dab some rubbing alcohol on the back of the other hand. Ask him to tell which hand feels cooler. Repeat this with several pupils.

2. On a humid day, the sweat from the body does not evaporate as quickly, because the air is holding as much moisture as it can already. The result is that the cooling effect of the evaporation is lacking and we feel hot and sticky.

3. When we are angry, our adrenal glands secrete more adrenalin. The flow of adrenalin through the bloodstream to the liver causes sugar to be released into the bloodstream. Energy is thus made available more quickly to the muscle cells.

4. Your pupils have become much larger in the dark. You are therefore unable to see until your pupils get used to the light and become smaller.

TEACHING SUGGESTIONS
(pp. 118–119)

Background: These two pages constitute a review of the concepts and terminology introduced in this unit.

What You Have Learned: This is a summary of the entire unit, with new words in boldface type.

Checklist of Science Words: Remind the pupils that there is a *Dictionary of Science Words* on pages 358–364. They should consult this dictionary whenever they are unsure of the precise meaning of a word.

WHAT YOU KNOW ABOUT

Systems of the Body

What You Have Learned

The body's systems work together to maintain health and life. The **circulatory system,** which is made up of the heart, blood, **arteries, capillaries,** and **veins,** circulates the blood all through the body.

As the blood circulates through the body, it picks up products from one part of the body and drops them off at another. Oxygen and food are carried to and wastes are carried away from the cells.

The **digestive system** breaks down food to be used by the cells. Food mixes with saliva in the mouth, then goes to the gullet, to the stomach, and then to the small intestine. Whatever is not digested moves on to the large intestine.

The **excretory system** carries wastes out of the body through the large intestine, the bladder, and the skin. The **respiratory system** also carries carbon dioxide waste out of the body.

The **nervous system,** which is made up of the brain, spinal cord, and nerves, controls not only the ability to think but also the ability to react to the world around you.

Other parts of the body, such as bones, muscles, and **glands,** also work to maintain life and health.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

bladder	cerebrum	kidneys	sensory nerve
capillaries	diaphragm	motor nerve	spinal cord
cerebellum	diffusion	reflex	villi

What Is the Answer?

Write the numbers 1 to 10 in your notebook. Next to each number write the answer to the question below.

1. Which blood vessels carry blood back to the heart?
2. Which blood vessels are smallest?
3. Which blood vessels carry blood away from the heart?
4. What is the beat in an artery called?
5. What instrument does the doctor use to hear your heartbeat?
6. In what part of the digestive system is digestion completed?
7. What are the little "fingers" on the inner wall of the small intestine called?
8. In what part of the body are there 2 million filters?
9. What part of the brain takes care of coordination?
10. In what part of the brain does thinking occur?

Name the Parts

Below you will see the outlines of two systems of the human body. In your notebook name the numbered parts.

What Is the Answer?

1. Veins from all over the body empty into the large veins, which carry blood back to the heart.

2. Capillaries are smallest.

3. Arteries carry blood away from the heart.

4. The beat in the artery is called the pulse.

5. The stethoscope is used to detect the heartbeat.

6. Digestion is completed in the small intestine.

7. These are the villi.

8. Filters are in the kidneys.

9. Coordination is regulated by the cerebellum.

10. Thinking takes place in the cerebrum.

Name the Parts:

1. Gullet	1. Throat
2. Stomach	2. Windpipe
3. Small intestine	3. Lungs
4. Large intestine	4. Diaphragm

TEACHING SUGGESTIONS
(pp. 120–121)

Background: These pages reinforce the concepts presented in the unit by suggesting activities that extend the pupil's ability to apply the learnings derived from the unit.

Can You Tell the Words?

1. Windpipe
2. Vein
3. Stomach
4. Capillary
5. Gland

YOU CAN LEARN MORE ABOUT

Systems of the Body

Can You Tell the Words?

Figure out the science words by adding or subtracting the names of the pictures and the words.

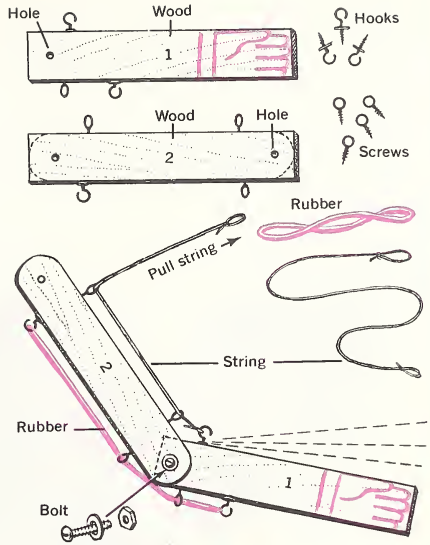
Making a Model

A model will show you how the elbow joint enables you to move your arm. You will need two pieces of wood about 12" long x 2" wide x ¼" thick, three cup hooks, four screw eyes, a bolt and nut, strong cord, and a rubber band.

Drill a hole in one corner of one piece of wood. Insert two cup hooks and one screw eye in the wood. This piece of wood will represent the two bones in the lower arm. Round the ends of the other piece of wood. Then drill a hole near each end. Fasten one cup hook and three screw eyes to this piece of wood. This piece will be the upper arm bone.

Next, join the two pieces with the bolt and nut. On the under side of the "arm," thread the rubber band through the screw eyes and slip it onto the two cup hooks. On the upper side, thread the cord through the screw eyes and tie one end to the hook.

Now pull the cord. What happens?



You Can Read

1. *All About the Human Body,* by Bernard Glemser. Discusses bodily functions.
2. *Your Body and How It Works,* by Patricia Lauber. About the human body.
3. *Your Heart and How It Works,* by Herbert S. Zim. The heart and the circulatory system are simply described.

Making a Model: Pupils can develop their understanding of the body by studying plastic models at a museum of natural history.

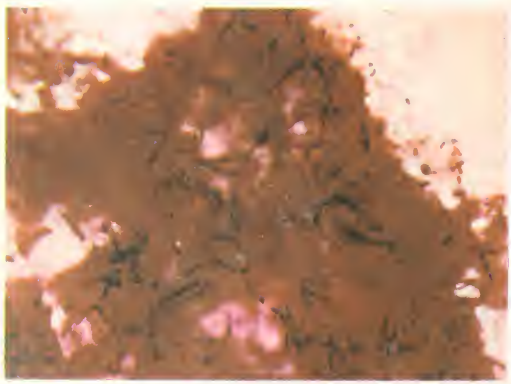
KEY CONCEPTS

Key Concept 1. Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

Key Concept 7. When equilibrium is upset in organism-environment interactions, regulatory mechanisms go to work to restore equilibrium.

CONCEPTS:

1. Diseases may result from deficiencies in diet, foreign materials, or degeneration of parts of the body. (Various theories have been advanced over the ages.)
2. Through scientific investigations, our present knowledge of causes and treatments of diseases has been developed.
3. Scientists from many countries have contributed to our knowledge of diseases.
4. Some diseases may be controlled by using chemicals, heat, antibiotics, and/or vaccines. Some diseases can be controlled by regulating diet and contact with materials that cause allergies; some diseases are controlled by surgery.



5

Other concepts appear under "Learnings to Be Developed" in each lesson found in the Teaching Suggestions.

Conquering Disease

What Is Disease?

Man's Battle Against Disease

5. The causes and proper treatment for some diseases have not yet been discovered, but scientists are working on them.

PROCESSES:

- Observing—Pages 127, 128, 137, 140, 143, 144, 159.
- Experimenting—128, 137, 140, 143, 144, 159.
- Comparing—127, 128, 137, 140, 143, 144, 159.
- Inferring—128, 137, 140, 143, 144, 159.
- Selecting—130, 137, 139, 149.
- Demonstrating—127.
- Explaining—138, 143.

TEACHING SUGGESTIONS
(pp. 124–128)

LESSON: What is disease?

Background: Primitive man knew that disease existed; he could observe the effects of certain illnesses—fevers, rashes, pains of the body. He saw that there was a difference between normal and abnormal functioning. But he did not know the cause or cure of sickness, or when it would strike. Disease could be recognized only by the outward symptoms familiar to him. Primitive man considered disease, together with other natural phenomena such as rain and sun, a magical happening. This magic held that spirits were responsible for all natural phenomena. Evil spirits caused disease. They entered a person's body and made it sick. Medicine men devised many rituals to drive away the evil spirits.

Today we may ridicule the ideas primitive man put forth, but it is interesting to note just how far his reasoning went. He *observed differences* and thus *concluded* from the differences that sickness was a special happening. He *hypothesized* about the cause, even though he explained what he experienced by reference to things that could not be tested. He also

In 1964 an entire town became involved in a national study of diseases. Almost everyone in Sudbury, Massachusetts, will be examined many times from then until 1979. Scientists hope that what they learn from this study may lead to discoveries that will help you to live free from disease.

What Is Disease?

Your body is made up of many systems that work together. But sometimes something happens to the body so that these systems do not work properly. When this happens, you are sick. When you are sick, you have a disease. There are many ways in which you can become sick. There are many diseases.

Diseases are caused by various things. A baby who does not get enough vitamin D may develop rickets, a **deficiency disease** (dih-FISH-un-see). The word *deficiency* means "a lack." If you lack certain vitamins or an essential nutrient, you may have a deficiency disease.

There are other kinds of diseases. There are diseases that you "catch" from other people. These diseases are called **infectious diseases** (in-FEK-shuss). They are caused by germs that infect the body. Colds, measles, and whooping cough are such diseases.

There are other diseases that occur when certain organs or systems of the body—such as the heart and blood vessels, the kidneys, the liver, and the nervous system—begin to wear out, or degenerate (dih-JEN-er-ayt). These are called **degenerative diseases.** Hardening of the arteries is one such disease. Sometimes degenerative diseases are the result of heredity, aging, or poor care of the body. At other times they are the indirect result of infectious diseases.

Primitive Man and Disease

Since earliest times, diseases have struck man. Primitive man was helpless against disease. Primitive man neither understood sickness nor knew what to do about it. He thought that evil spirits entered the body and made it sick. Some evil spirits caused a headache; others caused fever or a skin rash. To

This man is thought to have evil spirits within him that cause him to be sick. By wearing masks and chanting, the medicine men hope to drive the spirits away.

get well, he thought, one had to drive these evil spirits out of the body. To do this, one had to call for the help of a good spirit. The good spirit would defeat and replace the evil spirit.

Medicine men drove evil spirits away by beating, starving, or torturing the sick person. They believed that the evil spirits would leave if the patient's body were an unpleasant place in which to stay. Sometimes they tried to scare evil spirits away by wearing masks and costumes and by dancing and singing.

Early peoples believed in evil spirits, omens, and gods. For thousands of years, this belief affected their way of treating disease.

The Humor Theory of Disease

More than two thousand years ago, Hippocrates (hih-POK-ruh-teez), a Greek physician, believed that disease had a natural, rather than a magical, cause.

According to Hippocrates, the body had four important liquids, called the **humors** (YOO-merz). Hippocrates believed that people were in good health when the humors were balanced. When there was too much of one humor, sickness resulted. He thought the body itself could get the humors balanced again. To help the body get back its balance, he prescribed fresh air, rest, and certain foods for his patients.

attempted a kind of *problem solving* by devising rituals. The magical explanation and magical treatment of disease were ultimately discarded as irrational. Yet today we may hear peculiar ideas being offered as explanations of natural events and of sickness. These superstitions and myths are a carryover from the way people once thought about the universe.

Learnings to Be Developed:

Disease is any change from the normal condition or functioning of the body.

There are many diseases, which have different causes.

Developing the Lesson: Discuss the terms that explain the categories of disease, introduced on page 124.

After reading pages 124–126, pupils should understand how certain ideas about disease evolved. Point out that these attitudes persisted for thousands of years. Perhaps pupils can relate their experiences with a sick pet. They can then contrast their intuitive ideas about disease with those of a veterinarian.

Have you ever thought your pet was sick?

How did you know it was sick?

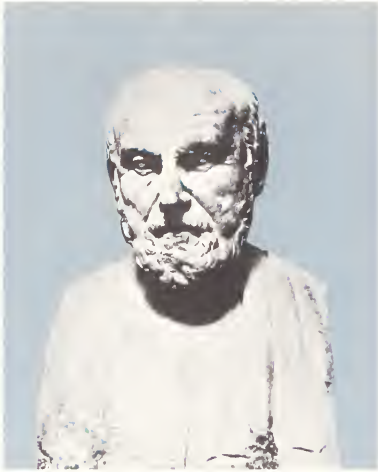
What could you do to find out?

Pupils may report that the pet didn't look, act, or seem "right," or they may volunteer specific symptoms. Pupils might have read about animal diseases in a good source, or they may have seen a veterinarian. Let them compare their own observations and problem-solving behavior with those shown by early man.

- *In what way did primitive man reason correctly?*
- *In what important ways was he unable to get good information?*
- *Why could he not test his explanation (evil spirits) even if he wanted to?*

Hippocrates (460–377 B.C.), the Greek physician, and Galen, a Greek physician who settled in Rome (164 A.D.), developed the first systematic ideas about disease. Their beliefs, recorded and passed on in teachings, constituted the beginnings of medical science.

- *Why do we say that Hippocrates believed disease had a natural cause?*
- *Could Hippocrates observe the four humors? Could he experiment on these liquids of the body?*
- *What did Hippocrates recommend as cures?*



Hippocrates, a Greek physician, is known as the founder of scientific medicine. Can you tell why?

Galen talks about treating diseases by using medicines. Find out more about Galen's ideas.

About five hundred years later, Galen (GAY-lun), a Roman, believed that everything in nature was made of four things: fire, air, water, and earth. Fire was hot, air was dry, water was wet, and earth was cold. A person was healthy if these four things were balanced in his body. If they were out of balance, sickness resulted.

To treat diseases, Galen used medicines made from plants, animals, and materials of the earth. Galen chose medicines according to the disease and the special property that each drug was said to have: hotness, coldness, wetness, or dryness.

Some of Galen's medicines really worked. For example, to lower a fever, Galen used medicines with "coldness." The "cold" substances worked against the high temperature of the body. The balance of hotness and coldness was restored. Can you guess one of the things Galen said had "coldness"?

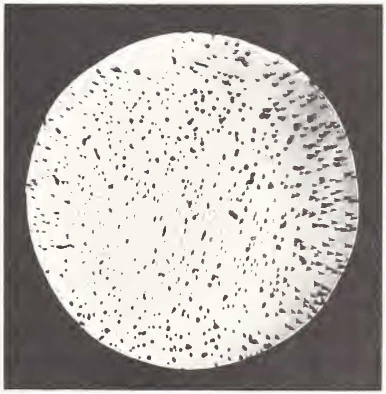
Discovering Microorganisms

There were other theories of disease. There were some men who thought that disease might be caused by tiny living organisms, too small to be seen by human eyes. The invention of the microscope made it possible to find out if such organisms existed.

You may remember that Anton van Leeuwenhoek made lenses as a hobby. His lenses were very small, but they magnified objects as much as two hundred times. Leeuwenhoek looked at all sorts of objects—skin, hair, ivory, and the wings of flies. He discovered a new world. Then, in 1675, he happened to study a drop of pond water. He saw tiny objects moving around. They seemed to be alive. Leeuwenhoek called them "animalcules." He was probably the first man in history to see these tiny living creatures. These tiny organisms were one-celled animals now called **protozoa** (proh-tuh-ZOH-uh).

You, too, can see protozoa. Collect some water from several places in a pond. Look at a few drops under a microscope. How many different kinds of living things do you see?

After Leeuwenhoek's discovery of protozoa, many other kinds of microscopic life were found. Organisms too small to be seen by the unaided eye are called **microorganisms** (my-kroh-OR-gun-iz'mz). Microorganisms are found in soil, in water, in the air, and on other living organisms. With the help of the microscope, man discovered a new world of living things. Yet years passed before scientists found evidence connecting microorganisms with disease.



This photograph was taken through one of Leeuwenhoek's original microscopes, shown above. The photograph proves that Leeuwenhoek could see the shapes of the microorganisms he drew.

- *In what way was Galen's theory of disease similar?*
- *How did Galen choose the medicines he made?*
- *Do you know of any prescriptions or cures today that make use of hotness, coldness, wetness, or dryness?*

Galen originated many preparations using herbs or plants. Such preparations are still known as "galenicals." One is still in common use and is virtually unchanged since he formulated it: "cold cream," or rose water ointment. It was originally called *unguentum refrigerans,* literally "cold ointment."

The pupils may mention mud packs for insect bites, ice packs or cold, wet compresses for bruises; and dry or moist heat packs for headaches. Such treatments make use of the "elements" of Galen.

Some pupils may report various myths or superstitions about disease. Discuss such ideas as, "Playing with toads causes warts," "Throw salt over the shoulder to ward off evil spirits" (when salt is accidentally spilled), "A black cat means bad luck."

- *Why do these superstitions remain despite the victories of science over disease?*

The class should now read "Discovering Microorganisms," pages 126–127, and should be led to do the experiment on page 128.

- *What theory of disease is presented here?*
- *What instrument made it possible to find out that tiny organisms exist?*
- *What were the "animalcules" that Leeuwenhoek saw?*
- *What are all organisms too small to be seen without a microscope called?*

Follow-Up: After doing the experiment on raising protozoa (p. 128), the class may wish to concentrate many protozoa so that a drop placed on a slide will contain a large collection. Pupils can test some responses of the protozoa, which they learned about in Unit 4. Transfer the culture to a narrow test tube and cover all but the top third or quarter of the material with carbon paper.

- *Where do most of the protozoa gather? Why?*

Protozoa gather near light. They may be attracted to it; they may be responding to gravity or to subtle temperature changes; they may be attracted to greater amounts of oxygen near the liquid's surface.

How Can Protozoa Be Raised?

What You Will Need

cup of water	dead grass, hay, or straw	2 clean jars
clean white cloth		2 glass slides
hot plate	microscope	eye dropper
pan	2 cover slides	rubber bands

How You Can Find Out

1. Boil the water in a pan on a hot plate. Let it cool for at least an hour.
2. When the water is cool, pour an equal amount into each jar.
3. Place all the grass, hay, or straw in one jar. Do not put any in the other jar.
4. Cover each jar with a piece of cloth. The cloth can be held in place with rubber bands.
5. Place both jars in a warm, dark place for six or seven days. Do not move the jars.
6. After four or five days, use an eye dropper to take a few drops of water from one jar. Place the drops on a microscope slide. Rinse out the dropper.
7. With the dropper take water from the other jar and place some on another slide.
8. Cover the drops on each slide with a cover slide.
9. Examine both slides carefully with a microscope.
10. If nothing is seen, take fresh samples and try again.

Questions to Think About

1. Describe what you see.
2. Why do you use dead grass, hay, or straw?
3. Why do you boil the water?
4. If you see nothing, what reasons can you give as to why nothing grew?
5. How did the organisms get into the water?

Louis Pasteur examines a glass container to see if the liquid in it has spoiled. Did he need to have controls for his experiments? Explain your answer.

Pasteur Performs an Experiment

In ancient times there were many theories about the cause of illness. You have already read about three of them. None of these theories had been carefully tested. In the 1860's, a French chemist, Louis Pasteur (pass-TER), was trying to find out why wines spoil. His experiments led him to one of the greatest medical discoveries of all time.

French winegrowers asked Pasteur to help them discover why wines become sour. Pasteur knew that certain microorganisms were necessary for making wines. He also knew that other microorganisms, called bacteria, caused some solutions to sour. Pasteur believed that if these bacteria could be removed, the wines would not spoil. But they were too small to be filtered out.

Pasteur had an idea. He took some of the soured wine and gently heated it. Then he examined the wine through his microscope to find the bacteria. They were no longer there. The bacteria seemed to have been killed by the heat. Pasteur tried this many times and got the same results. This evidence led him to believe that heating wine would kill the bacteria and keep it from spoiling.

Pasteur performed an experiment to test his hypothesis. A ship was about to

TEACHING SUGGESTIONS
(pp. 129–133)

● **LESSON:** What is the germ theory of disease?

Background: In the early part of the 19th century, scientists had shown that certain diseases were associated with *microorganisms*. Some scientists believed that the microorganisms were the causes of diseases, but they had not proved this. Some scientists, too, rejected the idea that microorganisms arise by "spontaneous generation." In the middle of the 19th century, Louis Pasteur (1822–1895) met great opposition when he suggested that microorganisms, such as *bacteria*, do not arise spontaneously, but come from other living things like themselves. In 1864 Pasteur demonstrated conclusively that the microorganisms of putrefaction (bacteria that cause things to spoil or *decay*) come from the air. A few years later Pasteur was able to demonstrate the formation of highly resistant *spores* in several microorganisms. This showed *how* microorganisms arise from living things like themselves. Pasteur developed the method, named for him, called *pasteurization*. Today we pasteurize milk by heating it to 145° F. for 30 minutes.

Robert Koch (1843–1910) developed bacterial research into an exact technical science. He formulated the famous set of rules known as *Koch's postulates.* Through the successful work of Pasteur and Koch, a new science came into being. By the end of the 19th century, bacteriology had reached a very high standard and had become an independent science. Pasteur is justly called the "father of bacteriology," and Koch the "father of bacteriological technique."

Learnings to Be Developed:

Infectious diseases are transmitted by specific germs, or microorganisms.

Through scientific investigations our present knowledge of causes of disease has been developed.

Scientists from many countries have contributed to our knowledge of disease.

Developing the Lesson: After the class has read pages 129–131, on Pasteur's experiment, lead them to see what long-held belief his experiment proved untrue.

- *Why couldn't bacteria be removed by filtering them?*
- *What alternative procedure did Pasteur adopt to kill bacteria?*

sail. Pasteur placed two barrels of wine on board. The wine in one had been heated. The wine in the other had not. The ship sailed, and after ten months it returned. Both barrels were opened, and the wine was tasted. The heated wine had remained perfectly sweet. The unheated wine was not fit to drink. It had turned sour! Pasteur had learned how to prevent certain liquids from becoming sour. This process of prevention is called **pasteurization** (pass-ter-uh-ZAY-shun). Do you know how it is used today?

Pasteur had discovered a way to kill certain bacteria. Next he wanted to find out where the bacteria came from. How did they get into wine? Some people believed that the bacteria came from the wine itself. Pasteur thought that the bacteria came from the air. Pasteur did other experiments to test his ideas further.

Pasteur collected many liquids that were known to spoil. He placed each liquid in a separate glass container and heated it. Then he put tops tightly on these containers so that no air could enter. For months, the liquids remained in the jars. From time to time, Pasteur opened some of the containers. He opened them in such a way that little air could enter them. He examined sam-

These are Robert Koch's own drawings of stages in the life of the bacteria that cause the disease called *anthrax.*

ples of the liquids under a microscope. All of them were free of bacteria.

Then Pasteur opened some of the containers and let air enter them. After a short time, the solutions contained bacteria. Pasteur now had good evidence that bacteria were in the air. They got into the wine from the air.

Pasteur continued to work with microorganisms. His experiments led him to form the **germ theory of disease.** The theory states that infectious diseases are transmitted by specific germs, or microorganisms. This was one of the greatest medical discoveries of all time.

The Germ Theory of Disease

Scientists found many bacteria in the blood of diseased persons. Why were the bacteria there? Were they always in the person's body? Or were they there only when the person had a disease? No one knew the answers, but some scientists studied and experimented with microorganisms to find out.

Robert Koch (KOHK), a German physician, studied a disease called **anthrax** (AN-thrakss). This was a disease that cattle, sheep, and sometimes human beings got. One kind of bacterium was always found in the blood of diseased animals. Was this bacterium the cause of anthrax?

Robert Koch (seated third from left) journeyed into the jungle to study tropical diseases.

In his laboratory, Koch infected mice with anthrax. He examined the blood of the mice many times with a microscope. He learned how the bacteria grew and multiplied.

Koch also found something else. He learned that bacteria can grow coverings around themselves. In this form bacteria are called **spores.** Spores do not look like bacteria at all. Spores can survive almost anywhere—in air, water, and soil. Bacteria in the spore stage do not cause anthrax. But when conditions are just right, the bacteria grow out of the spores and multiply rapidly. Then they cause anthrax.

- *When he examined the heated wine under the microscope, what hypothesis did he form?*
- *How did he test his hypothesis?*
- *From what source did Pasteur suggest that bacteria arise?*
- *Why were people opposed to his idea?*

Review the germ theory of disease. So far, the pupils know about two kinds of microorganisms—protozoa and bacteria—and that bacteria exist everywhere in nature.

- *Where are bacteria found?*
- *How do bacteria get into the body?*

Have the class read pages 131–133 on Koch's experiments. Koch wanted to be sure that only one organism caused the disease *anthrax.* Koch studied how bacteria grow and multiply. Bacteria can grow coverings around themselves; those that have done so are called *spores.* After they grow out of the spore stage, bacteria multiply and cause disease. Koch discovered how to grow, or *culture,* bacteria. He prepared pure cultures, containing only one kind of bacterium. When they grow and multiply, bacteria of one kind form a colony, separate from other bacterial colonies.

Have the class look at the picture on page 130. Point out the spore stage (Figs. 1 and 2 in the picture). The lower part of the picture shows bacteria in stages of growth and multiplication. Look at the picture on page 132. Notice that in the colony all the bacteria look alike.

- *What did Koch see in the blood of animals infected with anthrax?*
- *Why did Koch want to distinguish among the different bacteria found in the infected blood?*
- *What "food" did Koch use to grow bacteria?*
- *What is the difference between a culture and a colony?*
- *How did Koch proceed to determine which pure culture caused anthrax?*
- *What can you tell about the life cycle of bacteria by observing a colony?*
- *What is the early stage of growth? Can spores survive well?*
- *In what stage does the bacterium cause disease?*

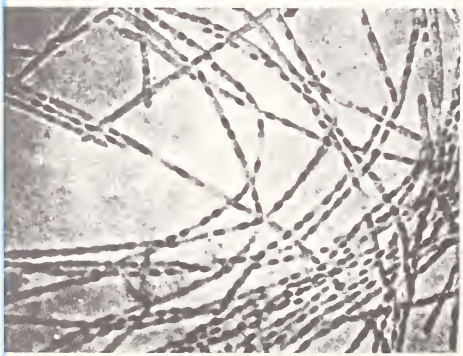
Follow-Up: Duplicate some of Pasteur's experiments. Take three common liquids (tea, milk, a soft

Growing Bacteria

Koch's next experiments gave scientists a new tool for investigating disease. He found a way of growing, or **culturing** (KUL-cher-ing), bacteria in his laboratory. To do this, he used a special substance called **nutrient agar** (NOO-tree-ent AH-gahr). Nutrient agar provides food for bacteria. It is made from seaweed.

Koch wanted to make certain that there was only one organism that caused anthrax. He took drops of pus from sores on a mouse with anthrax and spread the drops on a plate containing agar. Several different kinds of bacteria grew. The bacteria of each kind crowded together to form a different type of "spot," or **colony.**

Koch's photograph of a colony of bacteria.



But Koch wanted separate, or "pure," cultures. So he carefully took a little material from each type of colony and spread it over separate agar plates. When the bacteria grew, each plate had one and only one kind of bacterium. Now Koch had pure cultures. But which bacteria caused anthrax?

To find out, he injected healthy mice with bacteria from different colonies. Not all the mice got anthrax. Only bacteria from a particular kind of colony seemed to cause anthrax in mice.

Koch was still not satisfied. He cultured these bacteria from the sick mice and tested them again in healthy animals. Each healthy mouse developed anthrax. The cause of anthrax was always the *same* bacterium.

Koch's careful experiments proved that anthrax was caused by *one* microorganism. Now, for the first time, men had proof as to the cause of an infectious disease.

Finding New Infectious Bacteria

To help scientists find the bacteria that cause other germ diseases, Koch developed a set of rules. He believed that a scientist cannot be sure that a certain kind of bacteria causes a certain disease unless he follows the steps listed on the next page.

1. The organism must be seen in every case of the disease.

2. The organism must be grown in a pure culture.

3. Injected bacteria from a pure culture must cause the disease in a healthy animal.

4. The organism must be found in the newly infected animal and grown again in a pure culture.

Following these rules, scientists soon found the bacteria that cause **tuberculosis** (too-ber-kyoo-LOH-siss), **diphtheria** (dif-THEER-ee-uh), **pneumonia** (noo-MOH-nyuh), and **cholera** (KOL-er-uh).

Koch's rules were based on certain **assumptions** (uh-SUMP-shunz). An assumption is a statement whose truth is taken for granted.

Koch assumed that all infectious diseases were caused by bacteria. He assumed that all disease-causing organisms could be seen with a microscope. He also assumed that infectious organisms would grow on special food in a laboratory. Furthermore, Koch assumed that animals could get all the infectious diseases human beings got. Although these assumptions helped scientists find many disease-causing microorganisms, later scientists questioned the assumptions.

Iwanovski's experiments laid the groundwork for others investigating the causes of disease.

Viruses Cause Disease

In 1892 a Russian scientist, Dmitri Iwanovski (ee-von-UF-skee), studied a disease of tobacco plants. He found that the juice from infected leaves could carry the disease to a healthy plant. He believed bacteria were in this juice. To find the germs, he passed the juice through a filter with very tiny holes. It could trap the smallest bacteria. Only a clear liquid could pass through. To his great surprise, the clear liquid still infected tobacco plants. Iwanovski thought that there was something wrong with his filter and that some bacteria did get through.

drink, water, etc.). As soon as you open the bottles, place a small amount of each liquid in two clean, heat-resistant glass containers. Seal and set aside the first group. Boil the second group vigorously for 5 minutes, seal, and set side. Be sure to label the bottles. After a week examine each liquid under a microscope.

Why don't the boiled liquids show signs of contamination?

ADDITIONAL ACTIVITIES:

The four conditions needed to promote the growth of bacteria also exist in our bodies: warmth, food, moisture, and darkness. To obtain these conditions in the laboratory, use an incubator calibrated to the body temperature (about 99° F. or 37° C.). Get sterile nutrient agar Petri dishes from a local hospital or a laboratory. Nutrient agar contains much water, and will provide food and moisture. The incubator provides warmth and darkness. Ask individual pupils to press their fingers across the surface of the agar. Place in the Petri dishes a few hairs, assorted coins, rubber erasers, and pieces of paper. Incubate for 48 hours. Examine the dishes carefully under the microscope. Do not open the dishes or permit pupils to handle any that contain actively growing colonies.

TEACHING SUGGESTIONS
(pp. 134–137)

● **LESSON:** What other kinds of microorganisms cause disease?

Background: Toward the end of the 19th century many disease-causing bacteria were found. But continued investigations revealed that certain diseases could not be explained by bacteria. In the 1890's Martinus Beijerinck and Dmitri Iwanovski studied a disease of tobacco plants and could not isolate a disease-causing bacterium. Beijerinck hypothesized that the disease was caused by a molecule smaller than the bacterium. This molecule could not be filtered, could not be seen under the microscope, and could not be cultured. He called the molecule a *virus*. Since that time, scientists have learned how to culture viruses. They also invented the powerful electron microscope, which reveals different kinds of viruses and how they behave.

Is a virus a living thing? Viruses can be crystallized and stored for years without change, just as any nonliving chemical can be. But given the right kind of living tissue, the virus will enter the cell and reproduce, just as living organisms do. Scientists discovered a way to culture viruses outside the living organism. In 1949, at

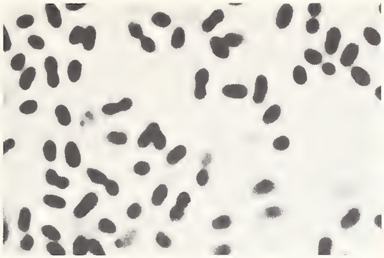
Beijerinck repeated one of Iwanovski's experiments and labeled the disease-causing molecule that is smaller than a bacterium a *virus.*

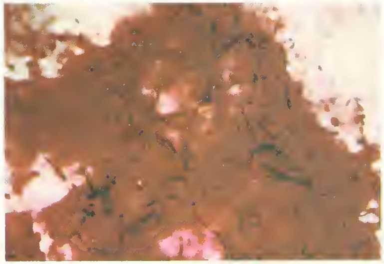
Five years later, Martinus Beijerinck (BAY-er-reenk), a Dutch scientist, repeated the experiment. With a microscope he carefully studied the clear liquid. No bacteria were found. Drops of the liquid were put on agar plates. No bacteria colonies grew; nothing could be cultured. But when he placed the juice on a healthy tobacco plant, the plant became diseased. Beijerinck formed the hypothesis that the cause of the disease was some kind of large molecule, but one that was much smaller in size than a bacterium. The molecule was too small to be trapped by a filter or seen with a microscope. It could not be cultured on agar. The scientist called the molecule a **virus** (VY-russ). *Virus* is a Latin word meaning "poison."

Friedrich Löffler (LOYF-ler), a German doctor and a pupil of Koch, studied foot-and-mouth disease. This is a disease of cattle. Löffler tried to use Koch's rules to find the microorganism that causes the disease, but they did not work. He was not able to culture it. His research showed that a filtered virus is the cause of foot-and-mouth disease.

This new evidence led scientists to doubt Koch's first assumption. Not all infectious diseases are caused by bacteria. Some infectious diseases are caused by viruses.

Löffler's work provided further evidence that not all diseases are caused by bacteria.





At the top left is a photomicrograph of bacteria that cause pneumonia, magnified 1,000 times. To the right are polio viruses magnified 77,000 times. At the bottom right, magnified 900 times, are fungus organisms that cause athlete's foot.

If you have a microscope available, obtain prepared slides of bacteria and fungi to show your class.

Finding New Infectious Viruses

What is a virus? A virus is a very tiny bit of protein, much smaller than a bacterium. The pictures on this page will give you an idea of the sizes of different microorganisms.

A virus cannot be seen with an ordinary microscope. It cannot be cultured on agar plates as ordinary bacteria can.

How can a scientist know that a virus causes a particular disease? How does he obtain evidence? A very important discovery helped scientists answer these questions.

Scientists discovered how to culture viruses. Viruses cannot get their food from materials such as nutrient agar. Viruses obtain food and multiply only inside a living cell. They do this because they use the cell's food-making processes. Now you know why earlier scientists could not culture viruses. They did not know that viruses must be grown inside living tissue. Today viruses are grown in little sections of animal tissue kept alive in laboratories. They are also grown in chick eggs.

In 1937, a very powerful microscope called the electron microscope was developed. In a compound microscope, the kind you may have in your school, beams of light are used to enable you

Harvard University, John F. Enders, T. H. Weller, and F. C. Robbins grew polio viruses on kidney tissue from a monkey. It thus became possible to study the growth of the virus in laboratory bottles. Dr. Enders and his group received the 1954 Nobel Prize in Medicine and Physiology for this work. Their discovery paved the way for the conquest of polio. (The story of Dr. Jonas Salk's achievement is told on pages 148–149.)

Learnings to Be Developed:

Viruses and fungi cause disease.

Scientists from many countries contribute to the knowledge of disease.

Developing the Lesson: Have the class read "Viruses Cause Disease," pages 133–134.

- *What three difficulties led scientists to conclude that a new organism, different from a bacterium, was present in the infected material?*
- *Did these difficulties conflict with Koch's assumptions?*

The disease-causing agent could not be filtered, cultured, or seen under a microscope—the basis for Koch's postulates. Point out to the class that rather than discard Koch's postulates altogether, sci-

entists restricted them to bacteria and at the same time searched for ways to identify the new disease-causing agent.

Have the class read pages 135–136 and study the pictures. Be sure pupils know that a fungus is a tiny plant.

- *Compare the sizes of the three microorganisms shown on page 135. Which is the smallest?*
- *What invention made it possible to see viruses?*
- *How have scientists been able to culture viruses?*
- *In what tissue or organism are viruses grown?*

Point out in regard to the picture on page 136 that viruses injected into the eggs will be grown as cultures. Scientists then examine the eggs under the electron microscope and learn how the virus grows, multiplies, and uses the living material of the egg.

Follow-Up: The pupils are now familiar with the four microorganisms that cause disease (protozoa, bacteria, fungi, viruses). Let them contribute to a chart on infectious diseases that can be written on the chalkboard. The chart should contain the following information: common name of disease (if any), medical name,

Eggs are injected with influenza viruses and then sealed. How do these eggs help scientists study diseases? How will you find out?

The electron microscope can magnify the organisms that cause "Asian flu" 27,000 times.

to see the object. Glass lenses then magnify the image so that you can see the object enlarged in size. There is a limit to how much glass lenses can enlarge an object, however. To see extremely tiny objects, it is necessary to use an electron microscope. In an electron microscope, beams of electrons are used to enable you to see objects. These beams of electrons behave much as light does. Instead of being focused by glass lenses, an electron microscope is focused by powerful magnets. An electron microscope can magnify thousands of times more than a compound microscope can. The electron microscope enables scientists to see viruses. They can identify the various kinds of viruses and discover how they behave.

Other new inventions and new culturing methods help scientists study and test viruses and find out what diseases they cause.

Ideas about disease have changed through the centuries. Unlike ancient beliefs, modern theories of disease are based on evidence. Many scientists from many countries have played important roles in obtaining this information. Today the causes of many infectious diseases are known. Knowing what causes a disease is the first step toward preventing and treating it.

Using What You Have Learned

1. Prepare a potato culture. Boil a potato. Cut several slices about one-quarter inch thick. Use a clean knife. Place each slice on a separate clean plate. Leave the potato slices exposed to the air for thirty minutes. Add a few drops of water to each plate. Then cover each plate with clear kitchen wrapping and put it in a warm, dark place. Examine each potato slice after a few days. What do you see? Colonies of bacteria may be any shape. They may be shiny or dull. Those found on potatoes are usually white, yellow, or orange. Do you also see molds growing? How can you tell?

2. Visit a medical laboratory to see how culture plates are used. While there, ask to see slides of blood from a healthy person and from a person who had whooping cough, pneumonia, or some other germ disease. What differences do you see in the slides?

3. If you live near a milk-bottling company, visit it to see how milk is pasteurized.

4. Malaria, influenza, typhus, and typhoid fever are spread in various ways. Read about how these and other diseases spread. Look up the life history of the protozoan that causes the most common kind of malaria. Report to your class about the protozoan. Use drawings and diagrams to illustrate your report.

5. Paracelsus, Vesalius, and Paré were three great doctors in the Middle Ages. Find out what contributions they made to medical knowledge.

6. Measles, scarlet fever, and pneumonia are caused by different organisms. Ask your doctor or school nurse to tell the class about these organisms.

symptoms, cause (if known), treatment, prevention. Design this follow-up as a group exercise. Pupils can form committees to do library research on a particular microorganism or on a particular disease. At the end of a class period each pupil should report on one disease and enter the information on the chart.

ADDITIONAL ACTIVITIES:

In Unit 2, pupils learned about the ordinary light (optical) microscope. In this unit they have been introduced to the electron microscope, thousands of times more powerful than the miscroscope used in class. Some pupils may be intrigued by the idea of particles of matter so small as to be invisible to the human eye. Radio Corporation of America (RCA) has information and illustrations comparing the optical and electron microscopes. A committee of interested pupils could be formed to pursue the topic.

TEACHING SUGGESTIONS
(pp. 138–144)

LESSON: How are infectious diseases controlled?

Background: One phase of medicine —surgery—had become quite sophisticated long before the germ theory of disease (and bacteriology as a science) was advanced. In the 1600's human anatomy was well understood, and surgeons performed difficult operations. But one consequence of an operation—infection of the wound—could not be explained. Pasteur had noticed that simple gunshot wounds, after treatment or after surgical attention, became infected and often caused death. He linked such infections to disease-causing organisms, to the bacteria he had been studying.

Joseph Lister (1827–1912), an English surgeon, was deeply influenced by the work of Pasteur. He reasoned from Pasteur's discoveries that wounds exposed to air would be susceptible to harmful bacteria and would thus become infected. Lister experimented with many chemical substances. He discovered that carbolic acid would kill bacteria before they could cause infection. Lister's work represents the first application of disinfectants to surgery. Since his time the control of infection has enormously reduced the risk of surgery.

Man's Battle Against Disease

You have learned that microorganisms cause many diseases. Infectious diseases are caused by various microorganisms. Polio, mumps, and German measles are caused by viruses. Whooping cough and diphtheria are caused by bacteria. Protozoa (one-celled animals) cause diseases called **malaria** (muh-LAIR-ee-uh) and **dysentery** (DISS'n-tehr-ee). Ringworm, athlete's foot, and some other skin infections are caused by plants called fungi. These different kinds of disease-causing organisms are found everywhere. They are often found in your body. Yet you are healthy most of the time. How can you explain this?

Scientists have learned how to control many harmful organisms and thereby control infection. To do this, they must stop the growth of microorganisms. Our bodies have several natural defenses against disease. But when these natural defenses do not protect you and infections do occur, you are able to overcome them in several ways. Special drugs and medicines help destroy microorganisms in the body. Then you recover from the disease.

Great progress has been made in the continuous fight against disease, but there are still many health problems that need to be solved. The goal of medical scientists is someday to free mankind of disease. Let us see what scientists have learned about preventing disease.

Disinfectants Kill Germs

Hundreds of years ago, doctors had learned ways of curing some diseases. Surgeons performed many operations. However, every operation was a great risk. Most surgical wounds quickly became infected. Joseph Lister, an English surgeon, wondered why this happened. He also wanted to know how the infections could be stopped.

Lister had treated many patients with broken bones. Some had simple fractures. In a simple fracture the bones do not break through the skin. Others had compound fractures in which the bones did break through the skin. He noticed that simple fractures never became infected. Compound fractures almost always became infected. Why?

There was a noticeable difference between the two kinds of fractures. One kind opened the skin and exposed tissue to the air; the other kind did not. Pasteur had shown that bacteria were in the air. If Pasteur were right, bacteria in the air might be falling on open

Joseph Lister directs the use of carbolic spray in one of the earliest "antiseptic" operations.

wounds and causing infections. Lister formed the hypothesis that, if the air were free of bacteria, wounds would not become infected. How could air be **sterilized** (STEHR-uh-lyzd) — that is, made free from living microorganisms?

After much experimentation, Lister in 1867 found a chemical that destroyed bacteria in the air. He tested his hypothesis by spraying the air in the operating room with this chemical, **carbolic acid** (kahr-BOL-ik). Some of the chemical was also put on bandages that covered wounds. One after another, his patients recovered. There were very few cases of infection. Lister had learned to use a chemical to kill bacteria before they could cause infection.

Chemicals that are able to kill germs are called **disinfectants** (diss-in-FEK-tunts). Soap is a good example of a common disinfectant. When you scrub your skin with soap, tiny flakes of skin come off. Microorganisms on these flakes come off at the same time. Many other organisms that remain on your skin are killed by chemicals in the soap. In these ways soap helps to control microorganisms and reduce the danger of infection. Scrubbing with soap and water can help you avoid disease.

Other chemicals are also good disinfectants. Most home medicine cabinets contain bottles of alcohol, hydrogen peroxide, and iodine. These chemicals are also disinfectants.

The terms used in this section should be carefully defined. *Sterilization* is a process that destroys all life in the area or on the object sterilized. (It is an absolute term; partial sterilization does not exist. But sterilization is a temporary effect, as objects or organisms can again be exposed to germs.) Sterilization may be accomplished by applying *heat, chemicals,* or *radiation* (such as X rays). *Disinfectants* are chemical substances that destroy germs on contact; *germicide* is a synonym. *Antiseptics* are chemical substances that inhibit or prevent the growth and development of germs. When concentrated, an antiseptic may be disinfectant; when diluted, a disinfectant may be antiseptic.

Learnings to Be Developed: Heat and chemicals are used to kill germs.

Developing the Lesson: Have the class read pages 138–139. Be sure they know the four kinds of microorganisms that cause disease. Help them to answer the question in the text by referring to the body's defenses. These natural defenses operate to prevent our getting certain diseases. Relate this fact to the importance of hygiene (skin) and healthful measures to avoid such minor infections as colds and sore throats.

- *What did Pasteur's experiment show about the origin of bacteria?*

What hypothesis did Lister make on the basis of Pasteur's work?

Name the process that kills germs.

What do we call chemicals that kill germs?

What disinfectant did Lister prove successful?

What common disinfectants are found at home or in the school?

Point out that not all household soaps contain disinfectants (germicides). Ordinary cleansing and toilet soaps do not contain germicides. These soaps are wetting agents. As they wet the skin, they loosen dirt and grease. Then rubbing the hands together and rinsing them in water provides effective cleansing. Point out also that there are many bacteria normally present on the skin that are harmless. Not all bacteria cause infection.

EXPERIMENT

How Do Some Chemicals Affect Microorganisms?

What You Will Need

ammonia	1 quart of pond water containing protozoa	microscope
lysol		4 cover slides
bleach	4 paper cups	4 glass slides
soap	medicine dropper	

How You Can Find Out

1. Get a quart of pond water containing protozoa, or grow your own protozoa as you did before. See page 128 if you do not remember how to grow them.
2. Collect several household disinfectants such as ammonia, bleach, lysol, and soap.
3. Stir the pond water gently. Then pour an equal amount of the water into four paper cups.
4. Add a very small amount of soap to one cup, a few drops of bleach to the next cup, and so on. Put only one kind of disinfectant in each cup.
5. With the medicine dropper place a drop of water from each cup on a separate glass slide, cover the slides with cover slides, and examine the slides under a microscope. Be sure to rinse the dropper after each use.

Questions to Think About

1. What do you see when you look at the water with the microscope?
2. What chemical is in the bleach?
3. What effect does the soap have?

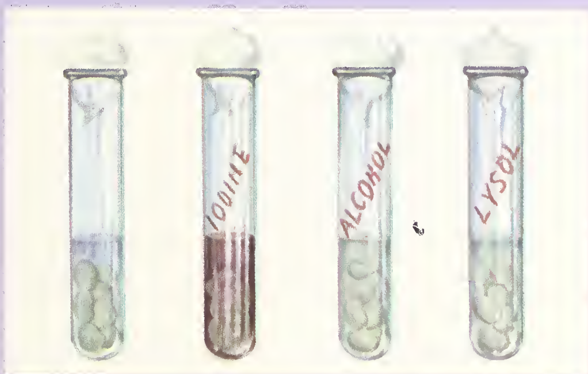
How Do Disinfectants Work?

What You Will Need

dried beans	4 test tubes	iodine
alcohol	lysol	sterile absorbent cotton

How You Can Find Out

1. Soak the beans in cold water for five or six hours.
2. Put several beans in each test tube and cover them with water.
3. Number the test tubes.
4. Do not add anything to test tube 1.
5. Add a little iodine to test tube 2.
6. Add a little alcohol to test tube 3.
7. Add a little lysol to test tube 4.
8. Stopper all the test tubes with sterile absorbent cotton, and put them in a warm place.



Questions to Think About

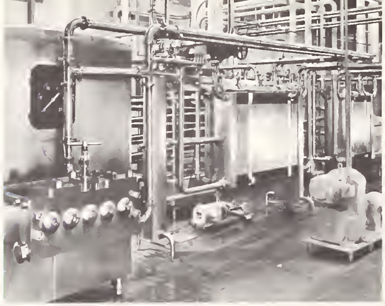
1. Remove the cotton and smell the contents of the test tubes. Do any of the test tubes have an odor?
2. What does the presence of an odor indicate?
3. How can you make certain that microorganisms cause the odor?

Pupils should do the experiments on pages 140 and 141 to see how disinfectants act on microorganisms. After examining the slides under the microscope, pupils should tell which chemical they think is the strongest (i.e., which kills a greater amount of protozoa most quickly).

In the experiment on page 141, let pupils get used to the odor of iodine, lysol, or alcohol if they are not already familiar with these chemicals. When the pupils test the results of their experiment, there may be a trace of the odor of these substances in the tubes. Of course, the class will easily identify the odor of decay in test tube 1. As a check on the experiment, let them compare a test tube of boiled water, left stoppered and standing for several hours, with test tube 1. There will be no odor from the boiled water. Use this check to lead into the subject of heat and microorganisms.

- *What did Pasteur learn about the effect of heat on bacteria?*
- *What process did Pasteur develop to prevent the souring of wine?*
- *What foods are treated by pasteurization today?*

Refer to pages 129–130 describing Pasteur's work. Have the pupils look at the pictures on page 142. Ask them to compare the modern sterilization equipment with Pasteur's methods (see picture on p. 129) and with the class laboratory apparatus. Be sure that pupils know the difference between pasteurization and sterilization. The method described in the text on page 142 is known as *flash pasteurization*. Regular pasteurization takes place in the temperature range 138–151° F. (about 145° F.) for 30 minutes.



This equipment is used to pasteurize milk. Why is it unwise to drink untreated fresh milk?

What precautions are taken to make operations free from infectious microorganisms?

This instrument is called an *autoclave*. It sterilizes materials at very high temperatures.

Heat Kills Germs

Scientists have found that microorganisms can be destroyed by heat. Pasteur used heat to kill microorganisms in his wine experiment. Heat is also used to kill germs in many of the foods we eat. For example, to kill germs in milk, the milk is heated to about 160° F. for 15 seconds. At this temperature most microorganisms in the milk are destroyed. Then the milk is quickly chilled and kept cold until it is used.

The process of heating milk to kill bacteria is called pasteurization. Many foods, particularly canned goods and dairy products, are pasteurized or treated by other heat methods. In this

How Does Boiling Affect Microorganisms?

What You Will Need

1 quart of pond water containing protozoa	old pan	medicine dropper
	glass slides	microscope

How You Can Find Out

1. Use a quart of pond water or culture your own protozoa. Remember that you may have to wait four or five days before protozoa can be found in the culture.
2. Examine the culture or pond water under a microscope to make sure protozoa are present.
3. Stir the culture or pond water gently.
4. Pour one half of the pond water or culture into an old pan and bring it to a boil.
5. Let the liquid cool for an hour.
6. With the medicine dropper place a drop of the liquid on a glass slide. Cover it with a cover slide. Then examine with a microscope.

Questions to Think About

1. Do you see any protozoa on the slide?
2. Make several more slides of other samples of this solution. Are protozoa present?
3. Can you explain what happened?

way, harmful organisms in foods are killed before they enter the body.

You remember that Lister used chemical disinfectants to prevent infection. In hospitals today great care is taken to prevent the presence of infectious microorganisms. Operating rooms are kept **antiseptic** (an-tih-SEP-tik), as free of germs as possible. Surgical instruments are sterilized with steam at very high temperatures. Everyone who enters the operating room must scrub carefully and wear sterile clothing, masks, and rubber gloves.

The class should do the experiment on page 143 to see how heat kills the protozoa in pond water.

- *Under what conditions do bacteria flourish?*

Review the four conditions needed for best growth (see p. 132): warmth, moisture, darkness, food. Elicit from pupils the opposites of these conditions. Discuss ways of preserving foods based on these opposites Remind pupils that cold destroys bacteria. Refrigeration is therefore an excellent way to preserve food.

You might set up a comparison experiment between dry (dehydrated) potatoes and normal potatoes, or dry corn flakes and moist corn flakes. You might also set up a comparison experiment between sunlight and darkness. A sunlamp or other ultraviolet source is an even more dramatic demonstration of the germicidal power of light. A good point to emphasize is that anything exposed to light is more likely to be cleaned than objects kept in the dark.

The experiment on page 144 is a good review of the material studied so far. Let the class experiment further by showing how an infection can be prevented by sterilizing with heat. Add a third perfect apple, apple *D*. Use the needle that punctured the rotten apple and that was injected into apple *B* in the experiment. But before injecting it into apple *D*, sterilize the needle by keeping it in a flame (match flame) until it glows. Then insert the needle into apple *D*.

- *If no infection results, what can you conclude?*

EXPERIMENT

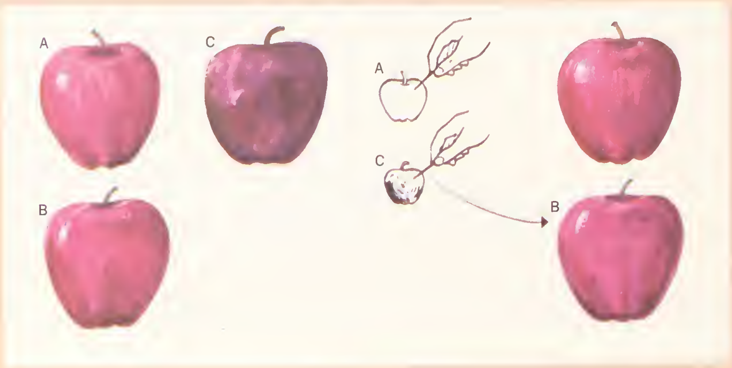
How Does an Infection Start, and How Can It Be Prevented?

What You Will Need

2 perfect apples — 2 needles
1 partly rotten apple — alcohol

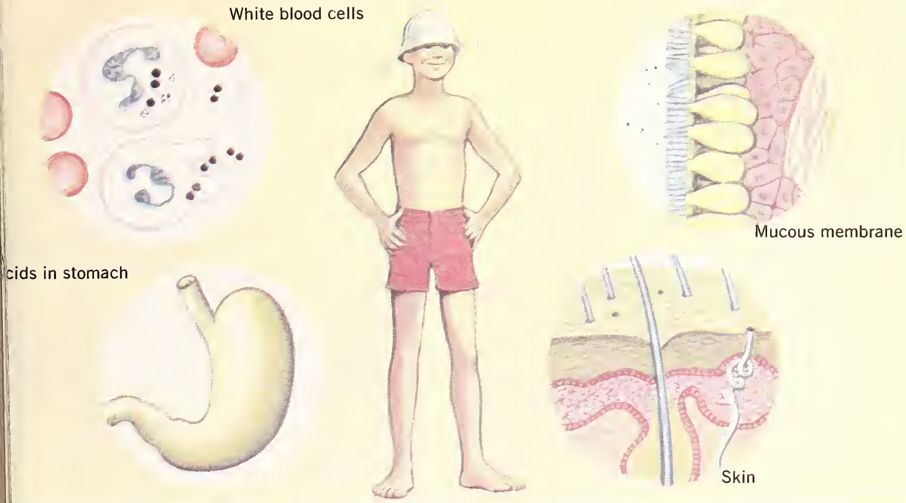
How You Can Find Out

1. Mark the perfect apples **A** and **B**.
2. Sterilize the two needles in alcohol.
3. Puncture apple **A** with one needle.
4. Puncture the rotten apple with the second needle and then inject apple **B** with this needle.
5. Keep apples **A** and **B** at room temperature for three to five days.



Questions to Think About

1. What happens to apple **A?**
2. What happens to apple **B?**
3. What have you found out about infection?
4. From what you have just seen, how do you think infection can be prevented?



THE BODY'S DEFENSES AGAINST DISEASE

Your Body Fights Germs

Your skin is your first line of defense against disease. Can you tell why? Harmful organisms that fall on the skin usually cannot get through it to cause infections. As you grow, tiny cells peel off the top layer of skin. The micro-organisms peel off, too. Then new skin cells appear on the surface. In this way your skin acts as a barrier against disease.

You are also protected by the moist lining inside your nose and throat. This lining, the **mucous membrane** (MYOO-kuss), traps dust particles and micro-organisms. When you cough or sneeze, many of them leave your body.

The digestive juices of the stomach also serve as protection. They contain acid, which kills many bacteria that you may swallow.

Even with these defenses, some harmful bacteria may remain alive in your body. When this occurs, the white cells of your blood may surround the bacteria and destroy them. Special substances in the blood help the white cells to do this. One of these substances attaches itself to each bacterium, and another causes the bacteria to come

TEACHING SUGGESTIONS
(pp. 145–148)

LESSON: How does the body fight disease?

Background: *Immunity* is the ability of the body to resist the invasion of germs and to prevent the development of a disease. *Natural immunity* does not last very long. *Acquired immunity* is temporary or permanent, depending on how it is acquired and the specific disease against which it protects. Acquired immunity is called *active* immunity if it results from *antibodies* developed in your body. It is called *passive* immunity if the antibodies are "borrowed" and there is no time to stimulate the body to produce its own antibodies. For example, in an emergency treatment of diphtheria a *serum* is injected; this serum is taken from horses who have manufactured antibodies to the disease.

Active immunity is brought about in two ways. One way is by recovering from the disease process itself. Disease such as *polio, smallpox,* and *chicken pox* confer lasting immunity. A second way is by injecting the germ itself (in a dead or weakend state) or by injecting the weakened waste product of the germ. Injections of a killed or live germ are known

as *vaccines;* live germs are weakened in the laboratory by heat or chemicals. Injections of the weakened waste product are known as *toxoids.* The waste product itself is called a *toxin.* In certain diseases it is the poisonous waste that causes the symptoms, not the microorganism itself. Toxins are harmful to body tissue and must be neutralized by injections of toxoids. Toxoids are produced in the laboratory by weakening the specific toxin by means of heat or chemicals.

Learnings to Be Developed:

Natural defenses of the body protect against harmful microorganisms.

The body can develop immunity to disease.

Vaccines, serums, and toxoids help the body develop immunity.

Developing the Lesson: Have the class look at the pictures on page 145. Let them refer to Unit 4 for additional information on systems of the body. The picture of the skin reveals two layers. The epidermis is the top layer. The dermis contains the sweat glands and the roots of the hairs that extend through the top layer.

- *In what ways does the skin keep you healthy?*

together in clumps. The white blood cells can then destroy the bacteria more easily and quickly.

You are born with these defenses against bacterial disease. They are the body's natural defenses against disease.

Immunity to Disease

Some disease organisms, particularly viruses, are difficult to destroy. Since they grow and multiply inside living cells, the cells must be destroyed to kill the virus.

All of us have been ill with one or more virus diseases. Measles, mumps, and chicken pox are examples of virus infections. When you recover, you are **immune** (ih-MYOON) to these diseases. You remain immune for so long that you are not likely to get these diseases again.

However, there are some virus diseases, such as the common cold, to which you are immune for only a short time. When you are no longer immune, you may become ill with the same virus disease again.

Men have known about immunity for hundreds of years. From time to time, different diseases had attacked entire countries. Many people died, but some never caught certain of these fatal diseases. No one could explain why. Finally, experiments with one of these diseases provided the clue for a new way to provide protection against disease.

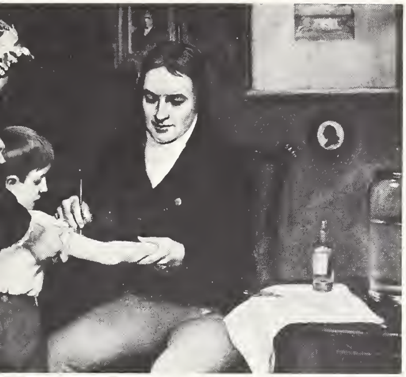
Long ago **smallpox** was a common disease. When it attacked, thousands died. Those who recovered were left with scars. Less than two hundred years ago, almost everyone carried the scars of smallpox.

To protect themselves from this dangerous sickness, people in China and Turkey purposely tried to give themselves mild smallpox infections. They hoped that they would be protected against a strong attack. It was a very risky treatment. Some survived, but many died of smallpox.

In England, milkmaids became ill with cowpox, a very mild disease of cows. When the milkmaids recovered, they did not get cowpox again. For some reason they did not get smallpox either. They became immune to both diseases.

This aroused the curiosity of Edward Jenner, an English doctor. He formed the hypothesis that cowpox and smallpox are alike in important ways. He believed that because of this those who recovered from cowpox also became immune to smallpox.

Jenner tested his hypothesis on May 14, 1796. First he collected some fluid



Dr. Edward Jenner gave his first vaccination on May 14, 1796. Today people in most parts of the world are vaccinated against smallpox.

from a cowpox blister. The fluid was injected into one of his patients, an eight-year-old boy. In a short time, the boy developed cowpox. But he recovered quickly. Jenner waited two months before going on with his experiment.

Now came the dangerous part of the test. Jenner injected the boy with smallpox. As Jenner expected, the boy did not get the disease. He was now **immunized** against smallpox. Jenner named this process **vaccination** (vak-suh-NAY-shun). Today, there are very few cases of smallpox in the world because people are vaccinated.

Following Jenner's discovery, scientists found ways of immunizing against other virus and bacterial diseases. One by one, new vaccines have been prepared. Today you can be immunized against diphtheria and polio as well as smallpox.

The English doctor's experiment was a landmark in medicine. It provided a new way to conquer disease. What would have happened to the boy if Jenner's hypothesis had proved wrong? The boy might have died of smallpox.

Experiments such as Jenner's are performed differently today. Research scientists working in laboratories try out experiments with animals before they are carried out with human beings.

Antibodies Provide Immunity

Vaccines help your body develop immunity to diseases. Immunity develops in a very special way.

When an organism enters your body, a new defense develops in your blood. As you fight off the infection, your body produces a special chemical substance. After a while, the substance makes the organism harmless. These special substances are called **antibodies** (AN-tih-bod-eez).

You produce antibodies for many kinds of disease-causing organisms. Some kinds of antibodies remain in the blood for a short time only. Others are

Review the role of the skin in getting rid of wastes and in maintaining a constant body temperature.

- *What part of the blood fights germs?*
- *Which microorganism is most difficult to destroy?*
- *Give examples of virus infections.*

After pupils read pages 146–148, discuss how immunity can be developed through inoculation. The terms *vaccination* and *inoculation* are often used interchangeably. Pupils may recall their own vaccination against smallpox; the skin is scratched, or slightly broken, and the vaccine administered on the open area. They may also remember that they were given deeper needle injections of toxoid for diphtheria and tetanus.

Review the two kinds of vaccines: killed and live.

- *Was Jenner's vaccine against smallpox live or killed?*
- *Who developed the live polio vaccine? Who developed the killed polio vaccine?*

Another example of a live vaccine is the one to immunize against *scarlet fever.* Another killed vaccine is the one used against *typhoid.*

TEACHING SUGGESTIONS
(pp. 148–149)

Background: In 1949, John F. Enders, a microbiologist at the Harvard University Medical School, had discovered that viruses could be grown in a nutrient broth in which a quantity of penicillin had been mixed. The penicillin prevented the growth of bacteria in the broth, but it had no effect on viruses.

Before Enders' discovery, it had been impossible to grow pure virus cultures. After his discovery, many scientists were able to grow virus cultures and experiment with them as they pleased.

One of the viruses that Enders grew was the one that caused poliomyelitis in children. Jonas Salk, who was also a microbiologist, began his experiments on polio viruses shortly after Enders' discovery.

Salk succeeded in killing the polio viruses with his vaccine in such a way that they could not harm the body but would nonetheless stimulate the production of antibodies as described in the text.

At the same time, another microbiologist, Albert B. Sabin, had become interested in Enders' dis-

there for many years. A few stay with you for the rest of your life. As long as you have antibodies for a particular disease in your bloodstream, you are immune to that disease.

Jenner knew the technique for vaccinating against smallpox, but he did not understand *why* his patients became immune. Now you can understand the reason. The mild cowpox virus caused the body to produce antibodies against cowpox. These same antibodies are also effective against the smallpox virus.

Today's medical scientists build immunity in two ways. Killed microorganisms may be injected into your body. In this form they are harmless, but your body still produces antibodies for that disease. The Salk polio vaccine is a good example of a *killed virus vaccine.*

Another way is to inject certain *live* organisms. These organisms have been selected because they are very weak. They are too weak to make you sick. The antibodies are produced quickly. The Sabin polio vaccine is a *live virus vaccine*. Both types of vaccines make you immune to polio.

By knowing how to produce immunity, medical scientists have helped protect millions of people against many virus and bacterial diseases.

PATHFINDERS IN SCIENCE

Jonas E. Salk

(1914–) United States

During 1954, a million and a half American school children took part in an important scientific experiment. Some of these children were given shots of a cherry-colored vaccine that, it was hoped, would protect them from the crippling disease called polio.

The rest of the children, acting as a scientific control, were given shots of a harmless cherry-colored liquid. Neither the children, their parents, nor their doctors knew whether the children were getting vaccine or harmless liquid. Only the scientists conducting the experiment knew.

Careful records were kept of how many children in each group got polio. The two sets of records were compared with each other and with records of previous years. The records showed that the vaccine worked and was safe. Newspaper headlines and radio and television programs spread the news throughout the world—scientists had learned how to prevent the dread disease polio.

Hundreds of scientists worked many years to develop a vaccine to protect us from the crippling disease called polio. One man in particular, Dr. Jonas Salk, brought

together many threads of polio research.

Great discoveries in any field are rarely, if ever, made by one man alone. Most often a discovery is the end product of years of thinking, exploring, observing, and experimenting. The results of all this work are published in scientific journals for all to read and accept or attempt to disprove. Often a researcher will use this knowledge in various ways.

About sixty years ago it was discovered that polio is caused by a virus. Scientists found that viruses could grow only in living organisms. It was only about twenty years ago that scientists discovered how to grow viruses in test tubes.

Dr. Salk looked for a vaccine that would kill the polio virus while it was in the bloodstream of a person. Such a vaccine, to be effective, would have to make the body produce enough antibodies to kill the polio virus before it could do any damage. Dr. Salk and his staff found that a vaccine that had polio virus in it worked. He and his staff found a vaccine that would kill the polio virus and at the same time would cause the body to produce antibodies, as the live virus does.

In 1954, when Dr. Salk was sure his vaccine was safe, he tried it on children. And in 1955, the world had a way to prevent polio.

covery. He had attempted, 10 years before Enders' success, to grow live polio viruses. Sabin was not convinced that the injection of dead polio viruses was the best or only way of fighting this disease. For one thing, Sabin believed that the dead viruses in the Salk vaccine lost their ability to stimulate production of antibodies after a short period of time. If live viruses could be used, they would continue to multiply inside the body and stimulate the production of additional antibodies for a longer period of time. Another advantage of using live viruses was that it would not be necessary to inject the vaccine into the body with a hypodermic needle. Instead, the vaccine could be swallowed in a sweetened fluid.

By 1957, Sabin had succeeded in growing viruses that he believed would provide protection against polio without causing the disease. To be sure, he first tried the vaccines on himself.

In 1960, the first Sabin vaccine was used in the United States. It, and the Salk vaccine, have succeeded in reducing considerably the number of cases of polio that occur in the United States and elsewhere in the world.

TEACHING SUGGESTIONS
(pp. 150–153)

LESSON: How are infectious diseases cured?

Background: The text states that men cured certain illnesses before they discovered the causes of those illnesses. We have seen how this could be so. Trial-and-error techniques, based on acute observations, often resulted in effective remedies. The prescriptions of Hippocrates and Galen, for example, have been passed on in medical teachings precisely because they work. For hundreds of years, plant, animal, and chemical medicinals (drugs) were used, and a good deal of experimentation went on. The study of medicine was linked with the practice of alchemy. Alchemists—"chemists of the Middle Ages"—developed various chemical compounds useful in medicine: preparations of sulfur, mercury, arsenic, and bismuth. Minerals, metal salts, and acids were used successfully to treat disease. Two metals of medieval medicine, arsenic and sulfur, have been given important new uses by modern chemists.

Learnings to Be Developed:

Chemicals and antibiotics can cure some infectious diseases.

Paul Ehrlich's research is an example of the way in which scientists test their ideas. He prepared 606 compounds to find Salvarsan.

Chemical Cures for Disease

Long before men discovered the causes of disease, they found remedies for several illnesses. Some of these remedies were plant products. For example, quinine is useful in treating malaria, a disease that may be caught in tropical countries. Quinine comes from the bark of cinchona trees.

When scientists discovered that bacteria cause disease, they started to search for other cures. Lister had shown that bacteria in the air could be killed by chemicals. But how do you kill bacteria *inside* the patient without harming the patient? Paul Ehrlich (EHR-lik), one of Koch's pupils, found a method.

Ehrlich had discovered how to color or stain bacteria so that they could easily be seen with a microscope. He used chemical dyes. Ehrlich knew that certain stains were absorbed by bacteria but not by normal body cells. He had experimented with a dye, trypan red, in the laboratory. This dye stains organisms that cause sleeping sickness. It also kills these organisms. Would this happen inside the body?

Ehrlich believed it would. After careful experiments with animals, he injected a patient with trypan red. The sleeping-sickness organisms were killed. The patient was unharmed. Ehrlich had discovered a chemical cure for a disease.

He set out to find other cures. Ehrlich, who was an expert chemist, prepared many arsenic compounds. Hundreds of these compounds were tested on infectious microorganisms. The 606th compound worked. It cured several diseases. In 1909, Ehrlich named compound 606 "Salvarsan," which means "safe arsenic." But too much arsenic is poisonous, and not every doctor used Salvarsan properly. Salvarsan was an effective cure for some diseases; but when it was not used wisely, the patient sometimes died.

Years later scientists discovered safer chemicals that are able to cure diseases.

Sulfa drugs are a good example. Many kinds of sulfa drugs were produced. Each type of drug worked well against specific kinds of bacteria. For some years sulfa drugs were the best chemical cures for bacterial infections, but soon better cures were found. They were far more powerful than sulfa. They have often been called the "wonder drugs." You know them as **antibiotics** (an-tih-by-OT-ikss). An antibiotic is a substance, produced by a living organism such as a bacterium, mold, or fungus, that fights germs.

Antibiotics Fight Disease

Most great medical discoveries result from careful experimentation. Antibiotics were not discovered in this manner. They were discovered by accident. A British scientist, Alexander Fleming, had been studying a common type of bacteria. Pure cultures of the bacteria were growing in nutrient agar plates. One morning in 1929 Fleming found that for some reason the bacteria on some of his culture plates had been destroyed.

Fleming examined the plates carefully to discover the reason. What he found surprised him. He discovered that the bacteria had been killed by a common green mold.

Fleming believed that some "something" made by the mold *Penicillium* had killed the germs. He called the "something" **penicillin** (pen-uh-SIL-in). He wrote a report about this discovery,

Alexander Fleming examines penicillin cultures. On the right is the mold *Penicillium chrysogenum*, a form of penicillium that produces almost all the world's penicillin.

Developing the Lesson: After pupils have read page 150, ask them to name all the plant and animal drugs they can think of. Some may mention iodine, alcohol, or mercurochrome (these are chemical disinfectants). Make two important distinctions here: between plant and animal drugs, and chemical drugs; and between disinfectants and drugs. Disinfectants kill germs outside the body, and thereby work to *control* disease. Drugs kill germs inside the body, and thus arrest or cure disease.

- *Why can't disinfectants be administered internally?* (They would kill useful microorganisms in the body.)
- *What was Ehrlich searching for?*
- *What material did he use to stain bacteria?*
- *Name medicines used today that dye or stain the skin.*

Ask the class if they have noticed the warning (poison) or caution labels on bottles of Merthiolate, Metaphen, Mercurochrome, and iodine. You might review some of the dyes and stains mentioned in Unit 2.

- *From what material did Ehrlich prepare Salvarsan?*
- *Why must Salvarsan be used with caution?*

In addition to the sulfa drugs, pupils may mention sodium bicarbonate, which neutralizes activity; and aspirin, a general analgesic. The action of aspirin is still not understood.

What are the "wonder drugs"?

From what living organisms are they made?

Have the class study the picture of the penicillin mold on page 151. Molds reproduce by forming microscopic spores. These spores are picked up by the wind, mingle with the dust in the air, and can be deposited anywhere.

What did Fleming discover about the green mold?

How did later scientists build on this discovery?

Is penicillin effective against all bacteria?

List side effects of penicillin.

Fungus infections were studied in the preceding lesson. Allergies are covered in the next.

Do particular antibiotics always work against certain bacteria?

What is a mutant bacterium?

When mutant bacteria multiply, what do they form?

What is the main characteristic of a strain of bacteria?

but no one seemed interested at the time. Fleming forgot about it, too! In 1938, two British scientists, Howard W. Florey and Ernest Chain, raised this same green mold in a laboratory. One of the substances from the mold was deadly against certain bacteria.

Penicillin was carefully tested on animals. When research scientists were as sure of its safety as they could be from extensive testing results, penicillin was used on human beings.

Penicillin became a powerful new weapon against disease. It can kill many kinds of bacteria, and it works quickly. For most people, penicillin is indeed a wonder drug.

But some people get *side effects*, such as hives, from using penicillin. Also, penicillin is not effective against all bacteria.

Scientists searched for other antibiotics without these difficulties. Many new antibiotics have been developed. Some of them come from soil molds. Some types of bacteria that penicillin does not kill are killed by some of these new antibiotics. Find the names of some of these new antibiotics and the diseases that the antibiotics are used to treat.

Sometimes antibiotics upset the normal balance of microorganisms in the body. Many types of bacteria and fungi are usually present in everyone. These microorganisms are necessary for good health. When antibiotics are used to kill harmful bacteria, many useful bacteria are killed as well. As a result, fungi may multiply much more rapidly than they normally do. Then you may develop a fungus infection which can also make you sick. In a few days, however, the helpful bacteria multiply and the balance of microorganisms is normal again.

Antibiotics have saved the lives of millions of people. But the widespread use of them has created another difficult problem. After a time, a particular antibiotic may no longer work against certain bacteria. At first, scientists could not understand why this happened, but now they believe they can explain it.

Most offspring of bacteria are exactly like the original cells. But occasionally an offspring is not altogether like others of its own kind. It is called a **mutant** (MYOO-tunt). Mutant bacteria may adjust differently to conditions around them. For example, a mutant organism may not be affected by the chemicals that affect other bacteria of the same kind. When this mutant organism multiplies, more of the same are formed.

Scientists are discovering new antibiotics very rapidly. Can you name any antibiotics that you have taken? What disease did they help cure?

Ordinary bacteria will be killed by an antibiotic. But there are some mutants that cannot be killed by the antibiotic. They continue to multiply in spite of the presence of the drug. A new **strain** of bacteria is formed. Its main characteristic is that it is **resistant** to that particular antibiotic. The new strain may now be passed on to another person. Often these new resistant strains are more dangerous than the original disease organism.

This problem is being solved by the continual discovery of antibiotics that are effective against new strains of microorganisms. As long as resistant strains appear, new antibiotics will be needed to control infectious diseases.

You have learned something about infectious diseases. But there are many diseases that are not infectious. This means that they are not caused by germs. These noninfectious diseases, some of which you will read about below, have other kinds of causes.

Noninfectious Diseases

Do you have hay fever or rose fever? Do you start to sneeze when you are near a cat or a dog? If so, you have an **allergy** (AL-er-jee). Some people break out in hives after eating strawberries. Others develop itching after eating eggs. A person who is sensitive to a specific substance is said to be **allergic.** Allergies are a form of disease.

From the picture on page 153, pupils should get a good idea of the vast research in antibiotics. Note the many different kinds shown here, and the variety of shapes and colors.

Follow-Up: Lead pupils to see that science is an interdependent and international venture. The work of Pasteur, for example, led naturally into the research of Koch. Stress the continuity of scientific advances. The class might make a chart or bulletin board display to show the international character of scientific achievements. Let them prepare brief biographies of each scientist studied in this unit.

ADDITIONAL ACTIVITY:

The class can grow its own molds very easily. Expose a piece of moist bread to the air for about an hour; divide into four pieces and put each in separate Petri dishes. Keep dishes in a dark place for a few days or a week. The common white mold, *Rhizopus,* will develop. It is unlikely that *Penicillium* will appear, but leave two dishes for another week. (*Penicillium* sometimes develops after *Rhizopus* on the bread.) *Penicillium* may be cultured by placing Roquefort cheese in a large, moisture-laden jar with an orange. *Penicillium* grows well on citrus fruit.

TEACHING SUGGESTIONS
(pp. 154–158)

● **LESSON:** What do we know about noninfectious diseases?

Background: The definition of disease offered in the first lesson of this unit—any departure from the normal state of the body—must be modified to specify the cause of a disease. We learned that there are two general categories of disease: *infectious* and *noninfectious*. Review what the pupils now know about infectious diseases. Add to the chalkboard chart a fifth disease-causing organism, *worms*. Ask pupils to find out what diseases are caused by worms (trichinosis, tapeworm).

By now the chart should include some of the following items. Bacterial infections: tuberculosis, diphtheria, tetanus, typhoid. Viral infections: smallpox, chicken pox, measles, mumps, rabies, polio, the common cold. Fungal infections: ringworm, athlete's foot. Protozoan infections: malaria, African sleeping sickness.

Learnings to Be Developed:

Noninfectious diseases are not caused by germs.

There are several different kinds of noninfectious diseases, of different origins.

Are any pupils in your class allergic to certain substances? How do they react to these substances?

Some people suffer from deficiency diseases. These diseases are caused by a lack of necessary food elements. For example, **scurvy** (SKER-vee) is a deficiency disease caused by a lack of vitamin C. If you drink orange juice and other citrus juices, you will not get scurvy.

You may have heard of people who suffer from diabetes or goiter. These diseases are caused by disturbances in production of hormones in the glands.

There are also diseases that are caused by harmful habits, such as the drinking of great amounts of alcoholic beverages or the excessive use of certain drugs.

People who constantly drink great amounts of alcoholic beverages are called alcoholics. They suffer from the disease called alcoholism.

Some people, called drug **addicts** (AD-ikts), misuse certain drugs and develop the habit of taking drugs regularly.

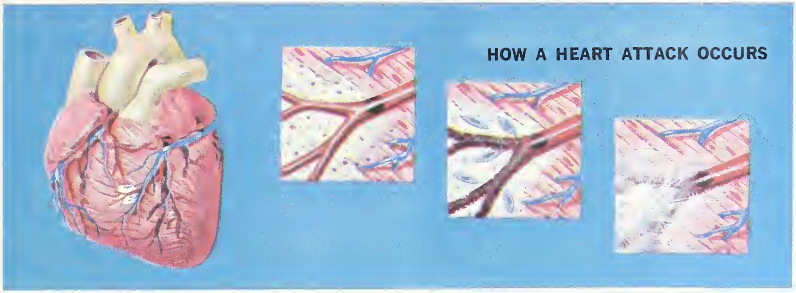
In 1964, the United States Surgeon General's report stated that smoking is closely linked to lung cancer and respiratory and other diseases. Thus smoking must now be included among the causes of disease.

At the beginning of this unit, we talked about degenerative diseases. These diseases result from the wearing out of such organs or systems as the heart and blood vessels, the kidneys, the nervous system, and the liver. Some of these diseases are partly the result of heredity and aging. Others are the result of infectious disease and poor personal hygiene.

Two of the most serious health problems in the United States are **heart disease** and **cancer.**

The heart may become diseased in several different ways. Occasionally the heart does not develop in a normal way before birth. For example, the heart wall between the lower chambers sometimes has an opening that does not belong there. The blood cannot circulate properly because of this opening. Surgeons can sometimes repair this kind of defect inside the heart. If the opening is small, a flap of muscle tissue may be sewed over the hole. A larger opening can be closed by stitching a plastic plug into the defect. Surgery can be used to correct several kinds of heart defects.

Another cause of heart disease is **rheumatic fever** (roo-MAT-ik). If rheumatic fever, which starts as a streptococcus throat infection, is not treated properly with antibiotics, the muscles



Sometimes trouble develops in one of the blood vessels of the heart. When an artery of the heart is blocked by a clot, the muscle fibers begin to fall apart. White blood cells ingest the dead tissue. After 5 or 6 weeks, other cells begin producing connective scar fibers. After about 3 months, a scar is formed. Why is it important that a scar forms?

and valves of the heart may become inflamed. This inflammation may also affect the arm and leg joints. A lengthy stay in bed is then necessary until the inflammation is cured. The physician tries to treat rheumatic fever so that rheumatic heart disease does not develop.

The most common type of heart disease occurs mainly in older adults. It involves the thickening of the inside lining of the small "coronary" arteries. These arteries supply blood to the muscles of the heart. This thickening of the lining of the arteries is called **arteriosclerosis** (ahr-TEER-ee-oh-skler-OH-siss). If the blood flows too slowly through the narrowed artery, a clot may form and the flow of blood will be blocked. Then the nearby muscle receives no oxygen. This causes a heart attack, or coronary attack. Doctors believe that arteriosclerosis is more common in those adults who smoke and in those whose diets contain a great deal of animal fat than in other people.

Physicians are learning new ways to prevent and cure heart disease. But it remains one of our most important health problems.

Cancer is another serious health problem. Most cases occur in middle and old age. Cancer can start in any organ of the body. Some of the cells of a certain organ grow out of control. Their rapid and wild growth forms a **tumor.** The enlarged tumor destroys the normal cells that are near it and interferes with the work of the organ. Such rapidly growing cells may spread and affect other areas of the body.

Developing the Lesson: Classify the noninfectious diseases into the following groups, and list on the chalkboard: organic diseases, functional diseases, degenerative diseases, allergic diseases, deficiency diseases, occupational diseases, psychosomatic diseases, and cancer. After pupils read pages 153–157, they will be able to discuss each type of disease.

An allergy is a sensitivity to a particular substance. Not all people are allergic.

- *Can you give examples of allergies? What are typical symptoms?*

Deficiency diseases are due to a lack of certain nutrients in the diet.

- *What is scurvy? How can it be prevented?*

Functional diseases are due to failure of a part of the body to function properly.

- *Give examples of malfunctioning of the glands.*

Degenerative diseases are caused by the wearing out of a part of the body.

- *What factors encourage degenerative diseases?*
- *What are two serious degenerative diseases?*

Organic diseases are due to failure of a part of the body to develop properly.

Describe a heart defect that is organic.

What is the treatment for heart defects?

What infectious disease may cause heart trouble?

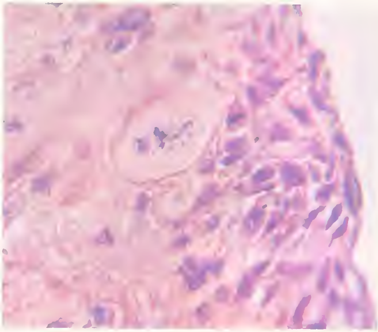
What is the best way to treat rheumatic fever?

Occupational diseases are caused by certain substances to which a worker is exposed on the job. Silicosis, a disease of the lungs, attacks coal miners and quarry workers. Radiation sickness is a hazard for workers in atomic industries.

Psychosomatic diseases are caused or aggravated by mental or emotional processes. Some so-called allergies are considered to be psychosomatic in origin. Under situations of emotional pressure, such disease symptoms as headaches (migraine), rashes, fever, and vomiting may appear.

Harmful habits also cause disease. Addiction to alcohol, drugs, or cigarettes interferes with health.

To what two diseases has smoking been linked? (Lung cancer and arteriosclerosis.)



Cancer cells grow out of control, destroying normal cells and interfering with the work of the organ they are growing in or near. Below you see a patient being given radiation treatments to arrest and possibly cure cancer.

Doctors have had some success in treating cancer. Surgery can be used to treat certain forms of the disease if the cancer is discovered before it has spread too far. The surgeon can remove the diseased tissue. But surgeons cannot positively tell whether or not the patient is cured. They must check the patient periodically for several years to make sure they removed all the cancer.

Some cancers are treated by **radiation** (ray-dee-AY-shun). Powerful rays are beamed at the cancer. The radiation may destroy the cancer cells, or it may slow down their growth for a while.

Why have we not discovered how to cure cancer? The real reason is that we do not know the cause of the disease. Scientists have developed a number of hypotheses. Some believe it is caused by viruses. They consider cancer an infectious disease. Others believe that certain irritating chemicals cause cancer. We take in many chemicals with food, water, and air. Do some of these chemicals cause human cancers? People who smoke cigarettes are much more likely to get a particular type of cancer than those who do not smoke. Many doctors believe that there is some chemical in cigarette smoke which causes cancer. They advise people to give up the cigarette-smoking habit or not to begin smoking at all.

Perhaps cancer is really several diseases with a number of causes. Some day scientists hope to find out.

The Battle Against Disease Goes On

Scientists have always battled to conquer disease. They have identified many of the organisms that make you sick. Ways of fighting infectious diseases with chemicals and antibiotics have been found. Vaccines have been developed to help you build immunity to many diseases. Today surgery does not involve the risk it did in former times. Today most of us can look forward to good health and a long life.

By evaluating evidence and testing ideas carefully, scientists have found the causes of and cures for many diseases. But some others are still mysteries. Many scientists are working to conquer these diseases. Some seek the causes, while others search for better ways to treat and cure diseases. Slowly, new evidence is being found. Another approach to the conquest of disease is a better understanding of the human organism. What characteristics does one person have that make him more likely to become sick? Why are some people hardly ever sick? Is there something different about their bodies that makes them resist harmful microorganisms? Why do many people in some families have diabetes? Why are some people allergic to ragweed while others are not? Why do cells begin to grow out of control? Scientists are trying to find the answers to all of these questions.

Man's battle against disease goes on. Someday mankind may be free of diseases. When will that day come? Nobody knows. Scientists are working toward that goal. Perhaps you will become a scientist, add to scientists' knowledge, and reduce the time it takes to reach the goal of a world free from disease.

- *What are the two biggest health problems in the United States today?*

Cancer is characterized by the abnormal growth and reproduction of certain cells in a part of the body. The causes of cancer are not yet known, but it is suspected that some forms are due to viruses. Other forms are so often connected with aging that they are regarded as degenerative diseases. Heredity may also be a factor in the development of cancer. Certain forms are related to smoking or to continued exposure to chemicals.

Ask the pupils to look at the pictures on p. 156.

- *How do the cancer cells in the tissue differ from other cells pictured in this book?*

Note that the cells are of different sizes. The enlarged areas are the cancer tumors.

- *How is cancer treated?*

- *What is the danger involved when cancer cells spread?*

- *Why must surgeons periodically check their cancer patients?*

Radiation affects cancer in two ways. It is used to treat and cure cancer. But overexposure to radiation can itself cause cancer.

Follow-Up: The class may wish to prepare a chart on noninfectious diseases similar to the one started for infectious diseases. Individuals or groups can take specific assignments, do the necessary research work, report to the class, and fill in the information on the chart. Topics might be broken down as follows: vitamin-deficiency diseases, mineral-deficiency diseases, alcoholism, narcotics addiction, heart diseases, etc. Two interesting questions that the class might explore are: "What is the relation of infection to noninfectious diseases?" and, "What diseases or symptoms of disease are caused by psychosomatic processes?"

THE FIGHT AGAINST DISEASE—A WORLD-WIDE BATTLE

Scientists battle disease on many fronts. New drugs are tested on animals before they are used on human beings.

To discover disease in its early stages, medical scientists use trucks carrying X-ray equipment to test people for chest diseases.

The medical ship "Hope" treats people in parts of the world where there are no or very few doctors.

Fighting and preventing disease is also the work of members of the Food and Drug Administration. They inspect sanitary conditions in food processing plants, make "control" inspections of drug manufacturers, and so on.

Using What You Have Learned

1. Test the effects of penicillin on a potato culture. You know how to make a potato culture. Prepare at least four cultures for your experiment. Ask your doctor or druggist for a penicillin tablet. When growths appear on the potatoes, crumble the tablet in a few drops of water. Soak small pieces of paper toweling in the penicillin. Place them on two potato slices. Cover the potatoes again and place them in a warm, dark place for several days. Then observe the cultures. Look closely under the penicillin-soaked paper and around the edges. Is there any difference between the cultures with penicillin and the untreated cultures? Were any organisms affected?

2. Test other antibiotics as you did penicillin and compare the results. A few samples of other drugs are all you need. Your doctor or school nurse might be able to get them for your experiment.

3. Read about a world-wide program to conquer disease. Write to the World Health Organization, United Nations, New York, N.Y., for booklets and other material.

4. Follow the current newspapers and magazines for new discoveries about the causes and treatments of diseases.

5. What is done by your community to protect you against dangerous diseases?

6. How are antibiotics tested to see which organisms they can destroy? Ask your family doctor to obtain antibiotic test rings for you. Ask him how they are used in laboratories.

7. Now that you have read this unit, can you tell why it took mankind so long to find out what the causes of most germ diseases are?

NOTES:

Use this space for any additional teaching suggestions you may have.

TEACHING SUGGESTIONS
(pp. 160–161)

Background: These two pages constitute a review of the concepts and terminology introduced in this unit.

What You Have Learned: This is a summary of the entire unit, with new words in boldface type.

Checklist of Science Words: Remind the pupils that there is a *Dictionary of Science Words* on pages 358–364. They should consult this dictionary whenever they are unsure of the precise meaning of a word.

Which Is It?

Measles—infectious disease.

Scurvy—deficiency disease.

Whooping cough—infectious disease.

Arteriosclerosis—degenerative disease.

Tell the Difference:

1. An *antiseptic* inhibits the growth of germs on contact; a *disinfectant* kills germs on contact.

2. An *antibody* is a specific substance produced in the blood that attacks a specific foreign particle (antigen); an *antibiotic* is a chemical, isolated from certain types of molds, that fights germs.

WHAT YOU KNOW ABOUT

Conquering Disease

What You Have Learned

Diseases have many causes. There are **deficiency diseases, infectious diseases,** and **degenerative diseases.**

Long ago, people thought there were four liquid **humors** in the body. They believed that people were in good health if the humors were balanced. Scientists later discovered that microscopic organisms, which they called **microorganisms,** live in the body. This led to the **germ theory of disease.**

To help scientists find the bacteria that cause diseases, Robert Koch developed a set of rules based on certain assumptions:

1. The organism must be seen in every case of the disease.
2. The organism must be grown in a pure culture.
3. Injected organisms obtained from a pure culture must cause the disease in a healthy animal.
4. The organism must be found in the infected animal and grown again in a pure culture.

Scientists later found that some diseases were caused by **viruses,** not by bacteria. Today great advances are being made to conquer disease.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

addict	antibodies	mutant	strain
allergy	disinfectants	radiation	vaccination
antibiotics	immunity	spores	virus

Which Is It?

Below are four diseases. Write them in your notebook and next to each one tell whether it is an infectious, degenerative, or deficiency disease.

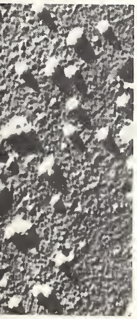
measles
scurvy
whooping cough
arteriosclerosis

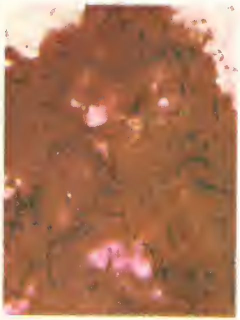
Tell the Difference

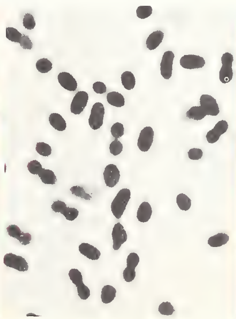
1. antiseptic—disinfectant
2. antibody—antibiotic
3. pasteurization—sterilization
4. vaccination—immunization
5. culture—colony
6. bacterium—virus

Do You Know?

Name three diseases caused by viruses.
Name two diseases caused by protozoa.
Name two diseases caused by fungi.
Name two diseases caused by bacteria.







3. *Pasteurization* is a process of heating liquids to kill harmful microorganisms; *sterilization* is any process employing heat, chemicals, or radiation that destroys all life on or in the particular object sterilized.

4. *Vaccination,* historically, is the immunization process of inoculating against smallpox; *immunization* is the process of injecting a specific material into the body in order to stimulate production of a specific antibody.

5. A *culture* is a growth of microorganisms in a favorable medium; a *colony* is a group of one kind of microorganism.

6. A *bacterium* is a one-celled, nongreen plant; a *virus* is a particle smaller than a bacterium that reproduces only in living cells.

Do You Know?

Viruses: polio, measles, mumps, smallpox.

Protozoa: malaria, amebic dysentery, sleeping sickness.

Fungi: ringworm, athlete's foot.

Bacteria: diphtheria, tuberculosis, typhoid, tetanus, anthrax.

TEACHING SUGGESTIONS
(pp. 162–163)

Background: These pages reinforce the concepts presented in the unit by suggesting activities that extend the pupil's ability to apply the learnings derived from the unit.

Match the Scientists:

1. Paul Ehrlich—Salvarsan.
2. Alexander Fleming—penicillin.
3. Edward Jenner—vaccination.
4. Robert Koch—anthrax.
5. Joseph Lister—sterilization.
6. Louis Pasteur—pasteurization.

What Are the Words?

1. Radiation
2. Immune
3. Sterilizes
4. Antiseptic
5. Antibiotic
6. Allergy
7. Culture
8. Heart

YOU CAN LEARN MORE ABOUT

Conquering Disease

Match the Scientists

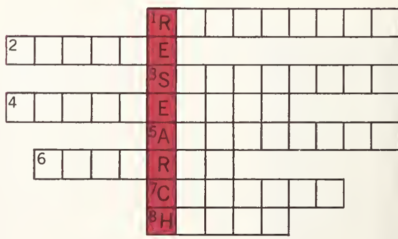
Can you match the names of the scientists with the words at the right?

1. Paul Ehrlich	anthrax
2. Alexander Fleming	sterilization
3. Edward Jenner	pasteurization
4. Robert Koch	penicillin
5. Joseph Lister	Salvarsan
6. Louis Pasteur	vaccination

What Are the Words?

Each letter in the word on the right is also a letter in a science word that you have learned in this unit. Find a word for each letter without using the same word more than once. Study the clues below for the words to use.

1. A method of treating cancer.
2. Protected against getting a disease.
3. Destroys bacteria.
4. Free from germs.
5. A substance produced by a living organism that fights germs.
6. A sensitivity to a specific substance.
7. The growth of bacteria on a specially prepared substance.
8. The organ concerned in one of the United States' most serious health problems.



You Can Visit

Perhaps your class will be able to visit a drug company. Here you will see how drugs are made and packaged. You may also have a chance to visit the laboratories where scientists are at work trying to find the causes and cures of many diseases. Ask the tour guide how long a drug must be tested before it can be sold.

You Can Read

1. *The Wonderful World of Medicine,* by Ritchie Calder. Tells about man's search for knowledge about himself and the ways to combat his diseases.
2. *Modern Medical Discoveries,* by Irmengarde Eberle. Tells how life-saving medicines such as penicillin were discovered and how they prevent the spread of disease.
3. *Walter Reed : Vanquishing Yellow Fever,* by Edward F. Dolan, Jr. How Walter Reed wiped out yellow fever.
4. *Polio Pioneers: The Story of the Fight Against Polio,* by Dorothy and Philip Sterling. The history of the disease and those who fought it.
5. *Master Surgeon: A Biography of Joseph Lister,* by Laurence Farmer. Lister's efforts to eliminate sources of infection.

You Can Visit: A dramatic as well as scientific project can be developed if you are able to take a portable tape recorder when you and the class visit the drug company or laboratory. Taped interviews of the scientists working there can be played back in class to re-experience and re-evaluate the visit.

NOTES:

Use this space for any additional teaching suggestions you may have.

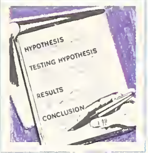
Do You Remember?

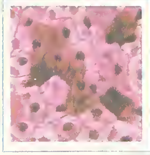
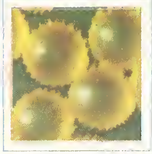
Scientists solve problems by putting them in the form of questions and developing *hypotheses* that are possible answers to these questions. A hypothesis must be tested many times to see if it is really the answer to a question. After a hypothesis is tested many times by many scientists and the same results are obtained, the hypothesis becomes a statement of fact. A *theory* tries to explain the facts that have been discovered. Theories may change as more hypotheses are tested and scientists add to their store of knowledge.

Probability theory is a theory about hypotheses themselves. It deals with how probable it is that any event will occur. Many hypotheses are so highly probable that they are accepted as being true. Scientists keep records to help others to repeat their work, to form theories, and to determine probabilities.

The *cell theory*, which says that all living things are made up of *cells* or of cells and their products, has a very high degree of probability. Scientists have studied many kinds of living things and found them to be made up of cells. All cells contain a *nucleus* surrounded by *cytoplasm*. The cytoplasm is surrounded by a *cell membrane*. In plant cells, the cell membrane is surrounded by a *cell wall*. Groups of similar cells make up tissues. Tissues work together to make up organs. Organs work together to make up systems of the body. All living things are *organized living systems* called *organisms*.

Every living thing begins as a single cell. Most animals begin as an *egg cell* that is *fertilized* by a *sperm cell*. The development of plants is similar to that of animals. *Embryology* is the study of the early development of living things. All living things need



certain materials provided by food to develop from a single cell to adulthood. The *rate of growth* varies throughout the lifetime of a living thing and is different for each living thing.

Your systems work together to keep you healthy. The digestive system turns the food that you eat into material your cells can use. The *blood* carries food to your cells and wastes away from your cells. Your *heart* pumps blood to your *arteries*. The blood goes from the arteries to *capillaries* and back to the heart through *veins*. Your *respiratory system* provides oxygen for your needs. You get rid of wastes through your *excretory system*. Every move you make requires the smooth working of your *bones* and *muscles*. Your *nervous system* helps all your systems adjust to change. Your nervous system and your *glands* also keep certain of your body's activities going automatically.

When your systems are not working properly, you have a disease. There are *deficiency*, *infectious*, and *degenerative diseases*. The first line of defense against infectious disease is your skin. Another defense is the *mucous membrane* lining your nose and throat, which traps dust particles and *microorganisms*. *Germs* that you swallow may be killed by acid in the digestive juices in your stomach. If any germs get beyond these defenses, the white cells of your blood may surround the germs and destroy them. Today we know that germs cause some diseases and *viruses* cause other diseases, but we still do not know the causes of many diseases. We can control or cure certain diseases with *disinfectants*, heat, *immunization*, chemicals, surgery, and *radiation*. But the fight against disease continues.

NOTES:

Use this space for any additional teaching suggestions you may have.

KEY CONCEPTS

Key Concept 1. Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

Key Concept 3. To find order in the natural environment, the scientist seeks basic units that can be put together in an almost infinite variety of ways; the cell and the atom are examples of such units.

Key Concept 4. All objects in the universe and all particles of matter are constantly in motion; man has discovered and stated the laws governing their motion.

Key Concept 5. The motion of particles helps to explain such phenomena as heat, light, electricity, magnetism, and chemical change.

Key Concept 6. There is a basic tendency toward stability or equilibrium in the universe; thus, energy and matter may be transformed, but the sum total of matter and energy is conserved.

Key Concept 9. The scientist has developed measures of space, time, and matter so that he can

6

Other concepts appear under "Learnings to Be Developed" in each lesson found in the Teaching Suggestions.

The World of Chemistry

The Chemist and His Work

Observing Crystals

Elements, Atoms, and Molecules

communicate explanations that are reproducible and make predictions about events in the natural environment.

CONCEPTS:

1. Substances are described chemically by their physical and chemical properties (melting and freezing points, solubility, reaction with other substances).
2. An element is the simplest form of a substance.
3. The atom is the simplest unit of an element; atoms combine to form molecules and compounds.
4. Atoms are made up of particles that have positive and negative electric charges.

PROCESSES:

- Observing—Pages 172, 175, 176, 178, 180, 181, 183, 186, 188, 191, 193, 195, 197, 198, 203.
- Experimenting—172, 175, 176, 178, 180, 186, 188, 193, 197.
- Comparing—172, 175, 176, 178, 180, 183, 186, 188, 191, 193, 195, 196, 197, 198, 203.
- Inferring—172, 175, 176, 178, 180, 183, 186, 188, 191, 193, 195, 197, 198, 203, 205.
- Classifying—190, 203.
- Selecting—173, 205.
- Demonstrating—174, 177, 180, 181, 183, 184, 185, 188, 191, 195, 198, 203.
- Hypothesizing—172, 195, 198.

TEACHING SUGGESTIONS
(pp. 168–169)

LESSON: What information is important to a chemist?

Background: The chemist must rely on his senses for the primary data needed in classifying materials. Much information is gathered by simple observation. In one national program for high school chemistry, pupils spent up to a week observing the physical changes of a burning candle.

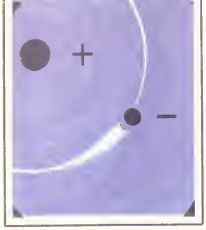
The physical properties of a substance are basic to a description of it. Make sure that the children are aware that common descriptions of color, temperature, hardness, texture, elasticity, and odor are valid descriptions for the chemist to use.

The chemist goes beyond the physical properties that are readily discernable to the less obvious chemical properties. To ascertain these properties he must devise other than ordinary procedures.

Learnings to Be Developed:

Chemists describe substances by listing their physical and chemical properties.

Among these properties are color, odor, taste, shape, melting point, and reactions.



As you learned, living things are the subject of biology. Biologists learn much by studying the cell—the basic unit of life. What everything is made of is the subject of chemistry. Chemists learn much by studying the atom—the basic unit of all matter. You will now read about the chemist and his work.

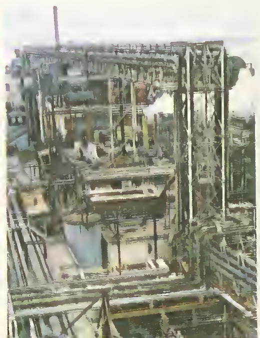
The Chemist and His Work

There is a rainbow of colors in your classroom. Look at the clothes your classmates are wearing. How many colors do you see? When your grandparents were in school, they did not wear clothes of all these colors. Most of their clothes were dyed black or blue.

Are you wearing something made of nylon, dacron, or rayon? If not, you probably have something at home made of one of these fabrics. Just thirty years ago, these fabrics did not exist.

In recent years chemists have made dyes, fabrics, and many other kinds of things of substances not combined in nature in the ways chemists combine them. Chemists study all substances. They want to know what the various substances are made of, how one substance is different from another, and how the substances interact. As chemists find out more about natural substances, they look for ways to produce new substances, such as plastics.

The materials on the left are fabrics made by scientists from various chemicals. The pipes in the factory on the right are made of various kinds of plastics.



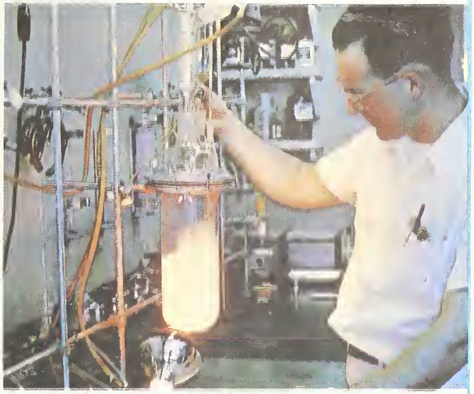
Chemists all over the world are searching for new chemical facts. The basic ideas of chemistry guide them in their search. You, too, can learn some of these basic ideas. When you learn some facts about crystals, solids, and liquids and about atoms and molecules, you will be able to see the world in some ways as the chemist sees it.

Observing and Describing Substances

As you walk along a road or through an open field, you may see weeds and flowering plants, birds and insects, sand and rocks. Some of the things you see are large; others are small. Some are colored; others are colorless. You can tell something about each thing that you see.

All your life you have been using words to describe objects. You know what these objects look like and how they act. You have tried to explain what they are and what they are made of. By observing and describing, you have been acting in the same way as a chemist acts.

A chemist spends much of his time observing and describing. A chemist must observe and describe substances very carefully to classify them and divide them into groups for further study and use. A chemist also describes things in special ways.



A researcher prepares a new synthetic chemical that will be tested as a mental-health drug.

A chemist begins a description of a substance by listing its **properties** (PROP-er-teez), or its special characteristics. A substance has **physical properties** and **chemical properties.**

Physical Properties

What are the physical properties of a substance? You might begin your study of a substance by asking questions such as: What does it look like? What is its color? What is its shape? How does it taste? What does it smell like? Color, shape, taste, and odor are physical properties. Physical properties are those that can be observed without the substance changing into something else.

Developing the Lesson: The object of this lesson is to show how the chemist observes and describes.

Have pupils describe various things in the classroom (window glass, pencil, chalkboard, chalk, etc.) and some familiar things found in the home, such as, salt, vinegar, sugar, etc. List these items and their descriptions on the chalkboard.

From these lists have the class categorize basic physical properties that are meaningful to all. End up with the following categories, which are the physical properties that are used by the chemist to identify and describe substances: color, odor, taste, state, density, freezing point, boiling point, melting point, and solubility.

For homework, have pupils list some things found in the home and describe their physical properties.

TEACHING SUGGESTIONS
(pp. 170–171)

Background: Lavoisier is called the father of modern chemistry for five very good reasons. First, he insisted on accurate measurements. For example, the quantities he measured in the experiments described in the text were quite small, and without accurate measurements he would not have been able to discover the changes in the weights of the tin and phosphorus.

The second reason that Lavoisier can be called the father of modern chemistry is his work in overthrowing the phlogiston theory described in the text and his recognition that the ashes of tin and phosphorus weighed more because they had combined with another element—oxygen.

The third reason is his recognition that in chemical transformations the masses of the reactants remain the same. This is the law of the conservation of mass—a fundamental part of modern chemistry.

The fourth reason is that Lavoisier originated the modern system of chemical notation, the use of symbols, and the practice of naming substances according to the elements of which they consist.

You already know many physical properties of many things. For example, you know that grass is green, a lemon is sour, and a rose is red. But a chemist must be more exact in his descriptions. A chemist must be exact about the color of an object because there are many shades of colors. He must be exact about taste because some things are sweet and others are sweeter. As a result, a chemist describes physical properties in greater detail than you do. He also describes certain properties you probably do not describe. One of these properties is the **state of matter** of a substance. As you have learned already, matter is anything that takes up space.

These researchers are testing various things to find out their physical properties. What do you see them doing in the picture?

PATHFINDERS IN SCIENCE

Antoine Laurent Lavoisier

(1743–1794) French

As a young man, Antoine Lavoisier (lah-vwah-zee-AY) studied law, because his father was a successful lawyer. But Lavoisier, instead of practicing law after receiving his degree, began to do research in many areas of science. He was so successful that at the age of twenty-five he was elected to the French Academy of Sciences.

Before Lavoisier did his research, chemists believed that when a material burns, it gives off a substance called *phlogiston*. They thought, moreover, that phlogiston is the substance that actually makes material burn.

Lavoisier experimented with tin. When he burned tin, he found that the ash that resulted weighed more than the tin had weighed before it had been burned. He was puzzled. How could the ashes weigh more if phlogiston was given off by burning? Shouldn't the ash weigh less?

Next, Lavoisier experimented with phosphorus. Again, the ash that resulted from burning weighed more than the original amount of the substance. Experimenting with sulfur, Lavoisier captured the gases given off by burning sulfur. He weighed these gases and found that they also

weighed more than the original amount of sulfur. Lavoisier reasoned that when a material burns, it does not give off a substance —instead, it combines with air. He believed, for example, that during the burning of sulfur, oxygen from the air combines with sulfur to produce the gases. Thus the gases weigh more than the sulfur did before burning.

Joseph Priestley, an outstanding English scientist, had made what he called "dephlogisticated air," or air without phlogiston in it. Lavoisier called this air *oxygen*. He set about to show that when a material burns, it combines with oxygen. After many experiments, Lavoisier upset the theory of the giving off of phlogiston by a burning substance. Lavoisier claimed instead that *when something burns it combines with oxygen.*

One of Lavoisier's great contributions was to simplify chemical terminology. He was bothered that the names for chemical substances—compounds and elements—did not follow an orderly pattern. Lavoisier noted that names in chemistry very rarely had any connection with the things or processes that they named.

Lavoisier developed terminology still used today to name the elements. And he contributed the "shorthand" of chemistry: instead of using hundreds of words to describe the chemical reaction in fermentation, for example, Lavoisier would write:

Fermentation $\rightarrow$ alcohol + acid + oxygen

Lavoisier was a genius who pioneered in other areas as well as chemistry. He urged new agricultural methods, suggested tax reforms, headed an institution that later became the Bank of France, and devised still other economic reforms. His abilities in both science and business made him a valuable advisor to the government.

Lavoisier is called the father of modern chemistry, for he succeeded in demonstrating the importance of chemistry, stimulating the imaginations of chemists, and interesting them in research.

The fifth reason is that Lavoisier wrote the first modern chemical textbook, *Elementary Treatise on Chemistry,* in which he set forth his ideas.

The last column on this page gives an example of fermentation, which might well be the basis for a class experiment or observation.

The following equations represent the formation of alcohol by a series of reactions involving the change of starch to maltose, of maltose to glucose, and finally the fermentation of glucose. The change of starch to maltose by the addition of water is called *hydrolysis* by chemists. When water is added to the maltose, glucose is formed. The last step is oxidation, a process by which yeast derives its energy to live and grow.

Starch + water $\rightarrow$ maltose

$C_{12}H_{22}O_{11} + H_2O \rightarrow 2\ C_6H_{12}O_6$
(maltose) (glucose)

$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$

Fermentation as represented by the last equation is inseparably connected with living organisms. The actual fermentation reaction is purely chemical but is brought about by specific enzymes secreted by cells or by yeast.

TEACHING SUGGESTIONS
(pp. 172–173)

LESSON: What are the states of matter?

Learnings to Be Developed:

The states of matter are liquid, solid, and gas.

Substances can be changed from one state to another by adding or removing heat energy.

Developing the Lesson: Assumptions have been made that pupils can operate a balance and read a thermometer correctly. Now would be a good time to discuss the differences between Centigrade and Fahrenheit thermometers.

- *Upon which physical properties are the thermometer scales based?* (Freezing point and boiling point.)
- *How is the freezing point on the thermometer determined?* (An unmarked thermometer is placed in a mixture of ice and water. The lowest point to which the mercury drops is designated 0° on the C. scale and 32° on the F. scale.)
- *How is the boiling point determined?* (The thermometer is placed in a beaker of boiling water. The highest point reached by the mercury is des-

DEMONSTRATION

How Does the Chemist Describe Things?

Combining estimating with accurate measurements

What You Will Need

balance scale ruler block of wood

How You Can Find Out

1. Try to guess the length, width, and thickness of the wood block.
2. Try to guess the weight of the wood block.
3. Then use the ruler to measure the length, width, and thickness of the block of wood.
4. Use the balance scale to find the exact weight of the block.

Questions to Think About

1. How do your guesses about the measurements of the wood compare with the measurements which you made with the ruler?
2. How does your guess about the weight of the wood compare with its weight as measured by the balance scale?
3. How do ordinary methods of observing compare with the chemist's methods?

States of Matter

Examine the cover of this book. Compare it with some water running from a tap. Compare the book cover and the water with the air around you. In what major way do these three things differ?

You can see that the book cover is a **solid,** the water is a **liquid,** and the air is a **gas.** Each of the substances is in a different state of matter. The three states are: solid, liquid, and gas. Every substance known is in one of these three states of matter.

Usually it is easy to decide what state of matter something is in. A solid substance has a definite shape. A rock keeps its shape in any kind of container. A rock is a solid. A liquid takes the shape of the container into which

it is put, but it remains at the bottom of the container. Alcohol and vinegar are liquids. A gas completely fills its container. Air is a gas. The air in your classroom fills every part of the room.

Changes of State

Some substances can change from one state to another. You have seen water change to a solid, called ice. Ice can change to a liquid, called water. Water can change to a gas, water vapor.

As liquid water becomes a solid or a gas, it changes from one state to another. An object sometimes changes from one state of matter to another when its temperature changes. The temperature at which such a change takes place is an important physical property. That is why chemists often use temperatures at which changes of state occur to describe substances.

Substances can be changed from one state to another by adding heat or taking away heat. When heat is used to change a solid into a liquid, we call the process melting. All substances that melt do so at a fixed temperature. This temperature is known as the **melting point** of the substances. Ice has a melting point of 32° Fahrenheit. The point at which water freezes is also 32° F. We call this temperature the **freezing point** of water. What do the processes of freezing and melting have to do with each other?

Chemists also use the **boiling point** to describe a substance. Water boils at 212° F. at sea level. Make a list of the boiling points of various substances, such as ethyl alcohol, ether, and gasoline. You can find these boiling points in the *Handbook of Chemistry and Physics.* (You will need to use the index of this thick reference book.)

Can you tell and describe the state of matter of each of the materials in the jars?

ignated 100° on the C. scale and 212° on the F. scale.)

- *How are the two scales divided between these points?* (100 equal divisions on the C. scale and 180 equal divisions on the F. scale.)

- *How do we convert from one scale to the other?* (If you know the F. reading, and you want to get the C.,

$$C = 5/9\ (F - 32)$$

If you know the C. reading, and you want to get the F.,

$$F = 9/5C + 32$$

Note, too, that for each rise of 1° C. there is a corresponding rise of 1.8° F.)

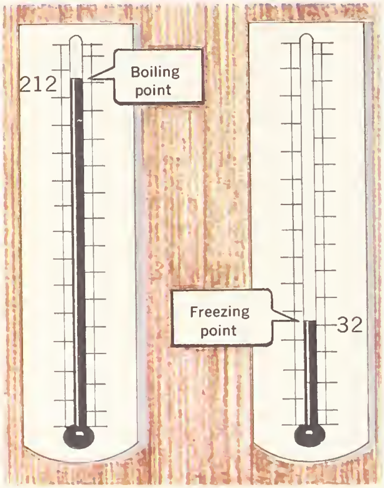
- *What do the processes of boiling and freezing have to do with each other?* (The melting point of a solid is the same as the freezing point of the same substance in liquid form. When 1 gm. of ice melts, 79 calories of heat are absorbed. When 1 gm. of water freezes, 79 calories of heat are released. The kinetic energy of the water molecules is lost in freezing, as the molecules become tightly packed in the crystals of ice, and it is released as heat energy. The reverse process occurs when the ice melts.)

TEACHING SUGGESTIONS
(p. 174)

Background: A simple solution is a homogeneous mixture of a solute (usually a solid) in a solvent that does not alter the chemical properties of the solute. The most common and most useful solvent is water. Alcohol is next in importance and utility.

A solution is *saturated* if, at normal temperature and pressure (S.T.P.), no more solute will go into solution. By raising the temperature of the solution, we can increase the amount of a solid that goes into solution. If, upon cooling, no solute crystallizes out, the solution is said to be *supersaturated.* In this event, jarring or scratching the container or dropping a "seed" crystal of the same substance into the container usually causes the excess solute to crystallize out immediately.

For gases in solution, several of the above conditions must be reversed. Chilling increases the solubility of a gas, because gases expand when heated. Agitation increases the rate of escape of gases from solution. (Remember what happens when you inadvertently shake the gingerale bottle or can just before opening it.) Therefore, to keep gases in solution, refrigerate the solution.



How do the boiling and melting points of a substance help the scientist to identify it?

Not all substances melt or boil easily. For example, it takes a tremendous amount of heat to make solid iron into iron gas. Solid iron becomes a liquid at 1795° F., and liquid iron changes to a gas at 5432° F. Also, a tremendous amount of heat must be taken from oxygen gas to change it into a liquid. Oxygen gas becomes a liquid at –297° F., which is a reading that is far *below zero.*

Such temperatures are not easy to get. But there are many changes of state that you can produce. These other changes of state do not need so much heat or cold. Sulfur is a solid at room temperature. You can easily change the state of sulfur. Heat a *small* amount of sulfur (about one-quarter teaspoonful) in a test tube. What happens when you heat the sulfur? *Sulfur melts.*

Solubility of Substances

Some substances dissolve readily in water. Other substances do not dissolve in water. If a substance dissolves in water, it is **soluble** (SOL-yoo-b'l) in water. An important physical property of any substance is whether it dissolves in another substance. This property is called **solubility.**

Here is a way to learn more about solubility. Put one teaspoonful of salt into a half cup of water. Stir the water. What happens to the salt? What kind of substance is salt? Then put one teaspoonful of sugar into another half cup of water. Now stir the water. What happens to the sugar? What kind of substance is sugar? *Salt and sugar dissolve. They are soluble.*

Now try putting one teaspoonful of calcium carbonate (chalk) into one-half cup of water. Stir the water. What can you say about the solubility of calcium carbonate in water compared with the solubility of salt and sugar in water?

Calcium carbonate is insoluble.

Do Substances Always Change from Solid to Liquid to Gas?

What You Will Need

large test tube	moth ball
test-tube holder	pan of water
burner	stand to hold the pan

How You Can Find Out

1. Place the pan of water on the stand.
2. Use the burner to heat the water to the boiling point.
3. Place one moth ball in the test tube.
4. Using the test-tube holder, place the test tube in the hot water for about two minutes.
5. Watch what happens to the moth ball.
6. Hold the test tube in the hot water for about two more minutes. Observe what happens.

Always hold test tube away from you when heating it.

Questions to Think About

1. Does anything unusual happen to the moth ball?
2. Do you see the usual changes in state?
3. What is the special name given to this process? How can you find it?

TEACHING SUGGESTIONS
(p. 175)

Background: The experiment on page 175 establishes that the sequence is not always operative. There are many cases where the liquid state is either imperceptible, nonexistent, or simply bypassed.

Mothballs (paradichlorobenzene or naphthalene) change directly into a gas from a solid. This phenomenon is called *sublimation*. The term applies to the transition, under suitable conditions, directly between the gas and the solid state of a substance. The most familiar sublimates are frost and snow. Iodine, caffeine, and carbon dioxide exhibit this type of transition also.

Follow-Up: Dry ice (solid CO_2) may be purchased in small blocks and exposed on the desk on an asbestos pad. Note the change from solid to gas (sublimation). Or, more dramatically, drop some solid CO_2 into a large beaker of water and watch it "smoke" and bubble away. The bubbles are CO_2 gas. The smoke phenomenon is used in the theater to produce stage "smoke."

Caution: Do not allow dry ice to come into contact with skin. Severe burns may result.

TEACHING SUGGESTIONS
(pp. 176–178)

LESSON: Does the solubility of a substance change with a change in temperature?

Background: Some substances are soluble; others are not.

The degree of solubility of a substance at different temperatures may be shown by a chart or graph.

Chemical dictionaries and handbooks will give the solubilities of substances in grams per 100 grams of water. Solubility tables classify substances as soluble, slightly soluble, or insoluble.

Learnings to Be Developed: A substance may vary in its physical properties under changing conditions.

Developing the Lesson: It might be profitable in this lesson to determine, quantitatively, the degrees of solubility.

Water is the most common solvent. The solubility of materials in water varies greatly. Let us determine the solubility in water of various substances.

Weigh carefully 5-gram portions of a number of common substances—salt, sugar, calcium carbonate, sodium bicarbonate (baking soda), boric acid, magnesium

You can do another experiment in solubility. Put one level teaspoonful of table salt into one-quarter cup (2 ounces) of water. Stir until the salt dissolves completely. Will the water dissolve more salt? You can see. Add another level teaspoonful. Stir the water. Keep adding measured teaspoonfuls of salt. What do you observe about the solubility of salt in water as more and more salt is added?

When a substance dissolves in a liquid, a **solution** (suh-LOO-shun) forms. In the experiment which you have just done, you made a solution of salt water. The process of forming a solution may be shown this way:

$$\text{salt} + \text{water} \longrightarrow \text{salt solution}$$

When you have added a certain amount of salt to the water, you reach a point at which no more salt will dissolve. You then have a **saturated** solution. When you have a saturated solution, some of the salt in solution comes out of the solution and forms solid salt again. This process is usually too fast to see. The particles that form are very small and are invisible. This process is always going on in a saturated solution. It is shown this way:

$$\text{salt} + \text{water} \rightleftarrows \text{salt solution}$$

Notice that a *reverse* process is occurring. Some of the salt is dissolving while some of the salt is becoming a solid. Both these things are happening at the same time. The lengths of the arrows show the relative speeds of the two processes. In a saturated solution, the salt is dissolving in the water as fast as the dissolved salt is changing back to a solid. If you keep adding salt to a certain amount of water, you soon reach the point where no more salt dissolves.

A comparison can now be made. Start with one-quarter cup of water. Add small, measured amounts of sugar. See how much sugar you must add before you have a saturated solution, or before the solution is balanced. A balance is reached when no more sugar dissolves. How much sugar is needed to saturate one-quarter cup of water? How much salt is needed to saturate one-quarter cup of water?

Solubility and Temperature

Make a saturated salt solution. At room temperature, about four teaspoonfuls of salt in a quarter cup of water make a saturated solution. You can be sure it is saturated by adding another quarter teaspoonful of salt. Stir. If the additional salt does not dissolve, then the solution is saturated.

What safety precautions should you follow when doing this experiment?

Now heat the solution, but do not allow it to boil. Does some of the additional salt dissolve? What can you say about the effect of heat on solubility?

Compare the effect of heat on a salt solution with the effect of heat on a hypo solution. Hypo is a chemical often used to make pictures from films. You can get some hypo from a photographic supply store.

About eleven teaspoonfuls of hypo in one-quarter cup of water make a saturated solution at room temperature. Try heating a saturated solution. Do not allow the solution to boil. Add small amounts of additional hypo. Notice how many more teaspoonfuls can be dissolved as you heat the solution. Compare this amount with the additional salt that was dissolved when you heated the salt solution. Do you find that the solubility of some substances increases greatly as you heat them? The solubility of some other substances increases only a little when you heat them.

The solubility of a substance at different temperatures is an important property of the substance. Often, chemists must know at what temperature a substance will dissolve in order to decide whether to use it for a certain job. The solubility of substances is affected by temperature changes. The solubility of some substances increases as the temperature rises. The solubility of other substances decreases.

sulfate (Epsom salts), etc., and place them in separate, labeled test tubes.

Add water, a little at a time, and shake vigorously after each addition, until no more material will dissolve. (If some of the material proves insoluble in the volume available in the test tube, transfer it to a larger container and continue adding water until it becomes obvious that no more will dissolve.)

Measure the solutions carefully in a graduated cylinder and note the results on the chalkboard.

Calculate the amount of water needed to dissolve each substance as a ratio, and check a chemistry reference book for correct solubilities. Some sample solubilities: salt, 1:2.8 (1 gm. in 2.8 cc. of water at S.T.P.[standard room temperature and pressure at sea level]); sugar, 1:0.5; sodium bicarbonate, 1:10; magnesium sulfate 1:0.8; boric acid, 1:18.

Perform the experiments referred to on page 176.

Experiment 1: Weigh a clean, dry beaker. Add 5 gm. of sugar to the beaker. Add a small amount of water, sufficient to dissolve the sugar. There is no visible evidence that sugar is present. Examine a drop of the liquid under the mi-

croscope. Now, drive off the water by heating to dryness. (Heat carefully to avoid loss by excessive boiling or by splattering.) After the beaker is dried and cooled, weigh again. All the sugar has been recovered.

Experiment 2: In two small beakers place sugar to a depth of about 1/2 inch. Fill both carefully with water. Heat one beaker until the sugar dissolves. Note the solution time in both beakers.

Experiment 3: Proceed as in Experiment 2. Substitute vigorous and continuous stirring for heat in one beaker until the sugar dissolves. Note the solution time in both beakers.

Proceed to the hypo experiment on page 177. Hypo is sodium thiosulfate.

Background: The following two points should be brought out by the experiment on page 178.

A gas is disturbed "out of solution" by agitation.

Increase in temperature reduces a gas's solubility.

These two behaviors of gases are just the reverse of the behavior of solids in solution.

EXPERIMENT

How Does the Solubility of Gases Change?

What You Will Need

1 cold bottle of soda — 2 heat-resistant glasses — source of heat

How You Can Find Out

1. Fill both glasses about halfway with soda.
2. Stir the soda in one glass slowly at first, and then stir it faster.
3. Slowly heat the second glass of soda.

Questions to Think About

1. Carbon dioxide, a gas, is dissolved in water to make soda. How does stirring change the solubility of gases in water?
2. How does heating change the solubility of gases in water?
3. Is there any difference in the way that heat changes the solubility of gases and solids in water?
4. Is there any difference in the way that stirring changes the solubility of gases and solids in water?

Chemical Properties

To better understand the work of chemists, one class did an experiment. The teacher took a piece of copper sheet and placed it in the flame of a burner. What happened? Would you see a change in the copper? The teacher then held a piece of steel wool in the flame. What happened?

When heated, the steel wool and the copper both changed. They combined with oxygen to form a new substance. The way they changed when they combined with the oxygen in the air is known as a chemical change, or **chemical reaction.** How substances combine for chemical reactions is determined by their chemical properties.

Both the steel wool and the copper combined with oxygen in the air. Many substances combine with oxygen. When paper is heated by the flame from a match, it combines with oxygen and changes to ash. Iron rusts when it combines with oxygen at room temperature. Aluminum hardly changes in the air.

Chemical properties are those that can be described only when a change occurs in a substance. Sodium combines with chlorine to form sodium chloride. Sodium chloride is known as table salt. When sodium and chlorine react chemically with each other, they are both changed. Their chemical properties can be observed when they combine and change. For you to observe and describe a physical property, the substance is not changed into anything else. When sodium chloride is dissolved in water, it is still sodium chloride. It tastes like sodium chloride. And, if the water is boiled away, sodium chloride remains. But sodium chloride has properties that are different from those either sodium or chlorine had before they were combined.

TEACHING SUGGESTIONS
(p. 179)

● **LESSON:** What is a chemical change?

Learnings to Be Developed: Chemical properties are those that can be described only in terms of a change that occurs in a substance.

Developing the Lesson: The following demonstration is a dramatic introduction to chemical properties, or their expression, which is chemical change. Put 4 tablespoonfuls of granulated sugar into a 250 ml. pyrex beaker. Add *concentrated* sulfuric acid, thoroughly wetting the sugar and leaving a thin layer above it. Wait a few minutes, during which time nothing occurs. Suddenly, with the evolution of great amounts of heat and steam, the sugar is carbonized into a column of carbon that extrudes out from the beaker. Dispose of contents carefully after the beaker has cooled. Remember: the sulfuric acid is still present; it merely dehydrated the sugar, as follows:

$$C_{12}H_{22}O_{11} + 11\ H_2SO_4 \rightarrow 12\ C + 11\ H_2SO_4 \cdot H_2O \uparrow$$

The water passes off as steam.

TEACHING SUGGESTIONS
(p. 180)

Background: This material will help you with the *Using What You Have Learned* section on page 180.

2. Crystals of sodium thiosulfate (hypo) are formed.

4. Heat increases the solubility of air in solution. Bubbles of air move through the water and rise to the surface. This increased motion of the air molecules "spreads" the molecules through the water, and hence increases the possibility of the air dissolving. This is the kinetic molecular explanation of why heating increases the solubility of certain substances.

5. The salt-water mixture freezes before the alcohol-water mixture.

Using What You Have Learned

1. Compare the solubility in water of table salt, barium sulfate, and silver nitrate.

2. Make a saturated solution of hypo at room temperature. Heat the solution and add about ten more teaspoonfuls of hypo. Cover the container. Put it in a refrigerator. What happens when the solution is chilled?

3. Collect small amounts of table salt, granite, quartz, and Epsom salt. Do an experiment to find out which of these substances dissolve readily in water.

4. You have learned that gases as well as solids can dissolve in water. What is the effect of heat on the solubility of air, a gas? Stir water in a jar to dissolve some air in the water. Stirring the water makes air dissolve more quickly than if the water were not stirred. Another way to dissolve air quickly is to pour water in a jar, cover the jar tightly, and then shake it. Use one of these ways to dissolve air in water.

Now find out the effect of heat on the solubility of air in water. Pour some of the water into a heat-resistant glass jar. Such a jar will not break if it is placed over a fire. A pyrex beaker works well. Heat but be careful not to boil the water. What do you see forming in the water as you start to heat it?

5. What can you add to water to keep it from freezing at 32° F.? Experiment by making one mixture of salt and water and another mixture of alcohol and water. Put the salt water and the mixture of alcohol and water into a freezer. Put a freezer thermometer into each container to measure the temperatures. What mixture freezes first? At what temperature does it freeze?

Observing Crystals

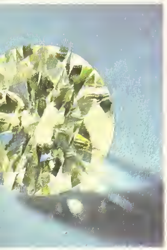
Perhaps you think of crystal as expensive glassware or as the beautiful mineral called quartz. But when the chemist talks about a crystal, he is talking about a solid substance that has a regular fixed shape regardless of its size.

Substances, such as snowflakes, that have a regular fixed shape are known as **crystals.** You have seen many crystals, such as diamonds and table salt.

When large crystals are crushed, the small pieces have the same shape as the larger chunk. When glass is broken, there is no regular pattern to the pieces. However, if a large piece of sodium chloride is crushed, each small piece has the same shape as every other piece. In crystals, because the shape is repeated, small and large particles have the same shape.

Many common substances have a hidden crystalline form. You can find this form in table salt if you examine it with a magnifying glass. Study the shapes of the crystals. Are their shapes different? What are their surfaces like?

Can you tell the names of the crystals below? How are they all similar?



TEACHING SUGGESTIONS
(pp. 181–183)

LESSON: What is a crystal?

Background: All solids are crystalline. The atoms that make up the crystals (as in the case of diamond, which is pure carbon) or the molecules (as in the case of sugar) are found in an orderly arrangement of lines and planes that can be described in geometric terms.

Since the discovery of X-ray crystallography by Laue in 1912, we have been able to determine the exact geometric pattern of crystals of any substance. The particular crystalline structure is directly related to, and helps explain, many of the chemical and physical properties of the substances examined.

The atoms of the crystal are held together by the electrical attraction they exert toward each other (for example, the positive ions of Na and the negative ions of Cl). If the electrical attraction is strong, a large amount of heat would be needed to disturb this attraction. (Salt will melt at 804° C., lead at 327.5° C., and gold at 1,063° C.)

In the presence of certain solvents, the crystals react variously. Water, a dipolar molecule (a positive electrical charge at one end and a negative electrical charge at the

other), can disrupt the crystalline structure of salt very easily, so that it dissolves without difficulty. Gold and lead are practically insoluble in water, but can be attacked and dissolved by various acids or combinations of acids.

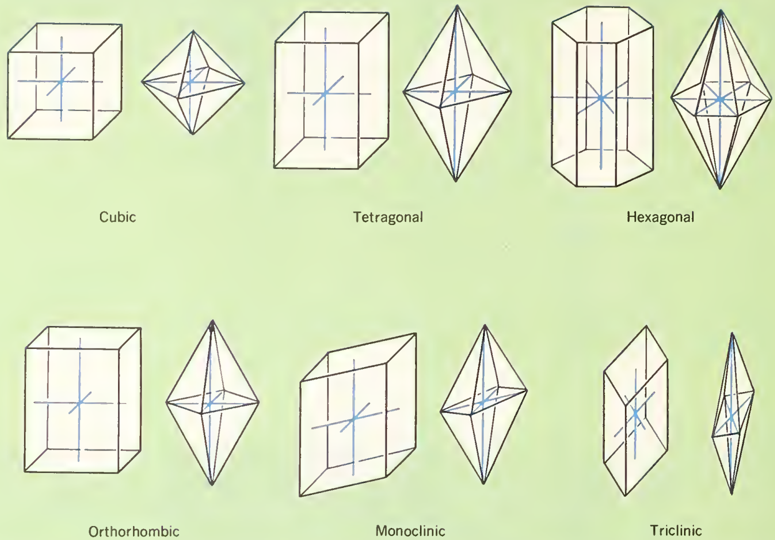
Learnings to Be Developed:

Many substances have a crystalline form.

The forms and sizes of crystals vary.

Developing the Lesson: Secure a microprojector (a microscope or hand lens will do, but will not be so effective). Make a saturated solution of salt in a cup or glass and place a single drop of the solution on a microscope slide. Place the slide on the microprojector and within a few minutes small dots should appear. After another short period of time they will begin to take on a square shape and eventually a cube should be discernible. The water is evaporating and crystals of sodium chloride are appearing, whose shape is a perfect cube.

Salt directly from a container will show this cubic shape, but irregularities are frequent because of damage in packaging and shipment. When salt from a container is used, an ordinary hand lens is sufficient for pupil viewing.



Look at each crystal shape and count the number of sides. What do all the crystal shapes have in common? What differences do you see among the crystals?

Different kinds of crystals have different properties. Some crystals are **cubic,** or six-sided, and others are **octahedral** (ok-tuh-HEE-drul), or eight-sided. Some crystals have a characteristic color.

All crystals have flat faces, sharp edges, and pointed corners. But crystals of different substances may have a different *number* of faces, edges, and corners. Some of the corners may be more pointed than others. And the faces may be different sizes.

Look at the pictures above. These are the six basic crystal shapes. Under each shape you will find the name of this shape.

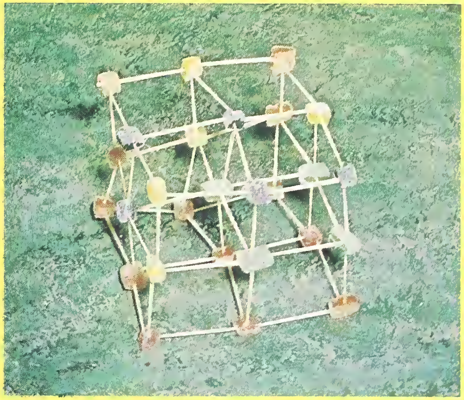
How Can We Understand Crystal Structure?

What You Will Need

a box of toothpicks soft wax or gumdrops

How You Can Find Out

1. Make 27 small (¼-inch) balls of soft wax.
2. Using 12 toothpicks, connect 8 balls of wax to make a cube.
3. Using 42 toothpicks and 19 balls of wax, add to the first cube so that it is 2 toothpicks long, 2 wide, and 2 high.
4. Continue to build the toothpick structure, but add half a toothpick at any point instead of a whole one. (You will, of course, need additional balls of wax.)



Questions to Think About

1. What happens to the shape of the cube as you continue to build with full-sized toothpicks?
2. What happens to the shape when half-sized toothpicks are used? What does this change tell you about crystal structure?

Proceed to a description of the basic shapes of crystals as found on page 182. The children could be encouraged to design the models of oaktag.

The *cubic* or *isometric* system of crystals has three equal axes (in blue on diagram) at right angles. Iron, table salt, galena (lead ore), and garnet have such axes.

The *tetragonal* system has three axes at right angles. Two axes are equal in length, and the third is different. A crystal of zircon is tetragonal.

The *hexagonal* system has three axes on a single plane at 60° angles to each other. A fourth axis is on another plane at right angles to the other three. A crystal of quartz is *hexagonal.*

The *orthorhombic* system has three unequal axes at right angles to each other. Sulfur is sometimes orthorhombic.

The *monoclinic* system has three unequal axes. Two of the axes are at right angles on a single plane, while the third is at a right angle to the plane of the other two. Gypsum and mica are monoclinic.

The *triclinic* system has three unequal axes, none of which are at right angles to the others. Feldspar is of this type.

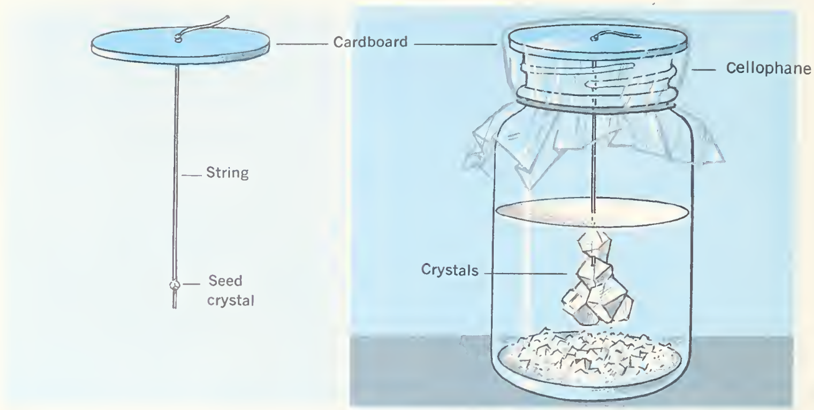
TEACHING SUGGESTIONS
(pp. 184–185)

LESSON: How are crystals formed?

Background: Two general procedures for growing crystals can be conveniently used in the classroom. You can suspend a seed crystal by a thread, as shown on page 184, in a solution of the crystal to be grown. Supersaturate the solution and seal the jar, or saturate the solution and leave the jar open to the atmosphere. In the second method you are depending on evaporation of the water and the deposit of excess ions or molecules on the seed. The seed will grow as the excess salt in the solution crystallizes on it. This is the quickest way to grow large crystals.

Many teachers with a microprojector prefer to grow small crystals on a microscope slide and show them on a screen as they grow through evaporation or directly from the melt of the substance.

Regardless of the method used for growing large crystals, the temperature should be as constant as possible. Changes in temperature change the degree of supersaturation; the seed may dissolve if the temperature rises.



Tie the thread around the seed crystal. Attach the thread to a cardboard cover cut to fit the jar. Place cellophane over the cardboard cover as shown in the picture.

Growing Crystals

To grow salt crystals, you begin with a single salt crystal. This crystal is called the "seed." Can you tell why? Hold the "seed" in some water which has as much of the same kind of salt in it as can be dissolved in the water. As you know, this is called a saturated solution. The "seed" will use the salt from the solution and will become larger.

To make sure that there will be enough salt for the "seed" to grow, use a solution that has been heated. Hot water can dissolve more salt than cold water can. As the solution cools, it becomes **supersaturated.** A supersaturated solution has more salt than is found in a saturated solution. The extra salt dissolved at the higher temperature will come out of the solution as it cools, and will help your "seed" to grow. How does the supersaturated solution help the "seed" to grow?

Any single crystal can be used as a "seed" for growing crystals. It is not hard to grow a crystal for study from salts like chrome alum or potash alum. Either of these chemicals will grow well and will give you beautiful crystals.

Prepare a saturated solution by doing the following: Stir 4 ounces of the alum into 19 ounces of water. Then heat the

mixture in a heat-resistant jar to about 122° F. Can you tell why the mixture should be heated?

You will need only a small part of the solution to obtain a "seed." Pour an ounce of the solution into a saucer, and store the rest in a Mason jar. You will use the stored solution when you are ready for the growing stage.

Let the solution in the saucer stand without moving it. As the solution cools and evaporates, the extra alum, which dissolved at the higher temperature, will come out. Some "seed" crystals will then form on the bottom of the dish. If no "seeds" appear, add an extra pinch of alum to the solution. When "seeds" appear, remove the best one with tweezers and attach it to a piece of thread as shown in the picture.

Now you are ready to grow the "seed." The saturated solution that you have stored in the Mason jar will serve as the growing solution. Add an extra ounce of alum and heat the solution by placing the jar in a pan of boiling water for about ten minutes. Then cover the solution and let it cool.

Prepare a cardboard cover for your jar, and attach the thread with the seed crystal to the cover. Place the cardboard on the jar, and cover the top carefully with cellophane. Put the jar in a cool place where the temperature will not change much. Do not move the jar while the crystal is growing.

Other Ways of Growing Crystals

The chemical phenyl salicylate, often called salol, crystallizes easily. Fill a test tube about half full with salol powder. Heat the test tube until the salol changes to a liquid. Set the test tube aside to cool. Do not move the test tube. Now drop a bit of salol powder in the liquid. Watch what happens. Examine some of the crystals with a magnifying glass. Describe what you see.

You have learned that you can grow a crystal in a supersaturated solution. Allowing a saturated solution to evaporate is another way to grow crystal. Evaporation may take several weeks, but it will give you a better-formed crystal than the sealed-jar method.

Prepare a saturated solution of potassium alum as you did before. Attach the seed to a thread. Tie the thread to the center of a stick so that the seed hangs from the stick. Lay the stick across the top of the jar so that the seed is in the solution. Cover the jar to keep out dust, but do not seal it. Put the jar in a cool place where the temperature will not change much. As the solution evaporates, what changes take place?

Saturate a solution at a fairly high temperature and allow it to cool so that a supersaturate is maintained. A cool closet is ideal for storage during the "growing period."

It will be quite obvious to you, but not necessarily so to the children, that the "growth" mentioned here is accretion and not growth as we use the term with regard to living things.

Learnings to Be Developed: Crystals grow by an orderly and precise addition of particles to the outside of a nucleus (foreign particle).

Developing the Lesson: An excellent motivational activity is the following. Add about 1 lb. of sugar (2 cups) to 8 oz. (1 cup) of boiling water and stir until the sugar is dissolved. Cool the solution; then pour it into a 250 ml. beaker. Suspend into the beaker several pieces of cotton thread or thin string from a pencil lying across the top of the beaker. Small crystals will begin to form in several hours. If the setup is left undisturbed for several days, large crystals (rock candy) will form. The crystals can then be distributed to the class to be eaten. It is important that the temperature be kept constant.

TEACHING SUGGESTIONS
(pp. 186–188)

Background: Many salts contain more than the charged atoms (ions) or neutral molecules. They also contain water. The water molecules are tightly bound into the crystal, and they have their own orderly part to play in it. Table salt, sodium chloride, does not have water molecules in its crystal structure. Copper sulfate does. The usual means of removing the water from a crystal is by heating, as in this experiment. The heat removes the water and in so doing destroys the basic crystal shape. Result: a fine white powder instead of a shiny blue crystal. Upon further heating this powder will either burn or else turn to liquid then gas.

When salt is heated, the only change that might be noticed is a liquifying of the crystalline mass.

Answers to the *Questions to Think About* are:

1. In the copper sulfate there was a color change and a texture change.

2. The water in the crystal was driven off.

3. No, because not all crystals contain water molecules as part of their structure.

EXPERIMENT

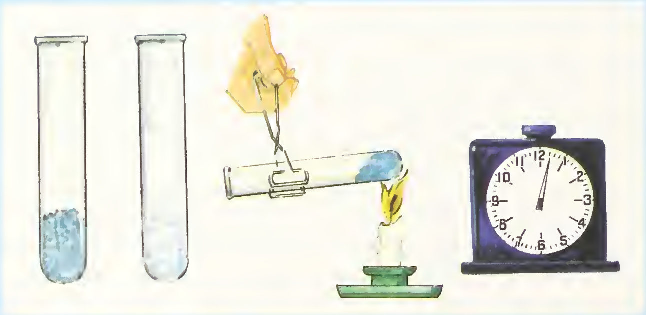
Do All Crystals Contain Water?

What You Will Need

several copper sulfate crystals	2 test tubes
several sodium chloride crystals	source of heat

How You Can Find Out

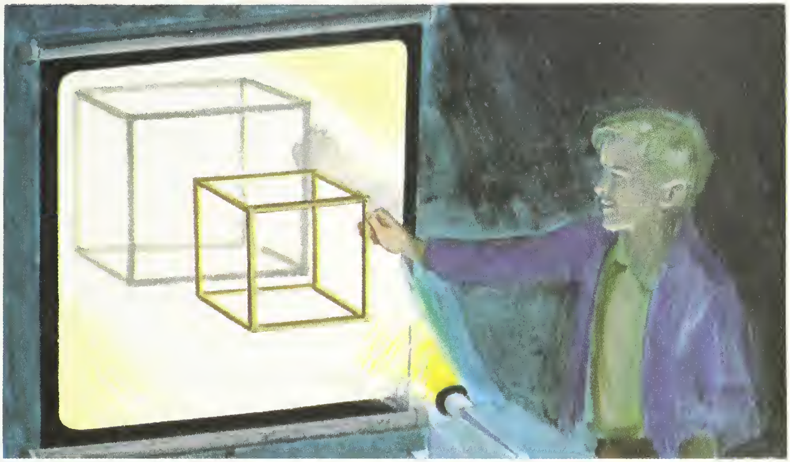
1. Place some copper sulfate crystals in one test tube and some sodium chloride crystals in the other.
2. Heat the test tube containing the copper sulfate crystals for two or three minutes.
3. Write down any changes that you see taking place in this test tube.
4. Heat the test tube containing the sodium chloride crystals for two or three minutes.
5. Write down any changes that you see taking place in this second test tube.



Questions to Think About

1. In which of the two substances was there a change in appearance?
2. How can you explain this change?
3. Is this kind of change found in all crystals?

The test tube should be tilted slightly downward when heated so that the water runs out of the tube away from the heated part. Say, "Notice the drops of water. Where do they come from?"



Crystal Size

The size of a crystal depends partly on the speed with which the crystal is formed. You can do an experiment to see that this is true. Prepare a saturated solution of Epsom salts. Pour the solution into three clean saucers. Put one saucer in a warm place, such as the top of a radiator. Keep another at room temperature. Place the third saucer in a cool spot. Observe the sizes of the crystals that form in the three saucers. In which saucer are the crystals largest? Is it the one from which water evaporated *slowest* or the one from which there was *the most rapid* evaporation?

Finding Out About Crystal Structure

Make a model of a salt crystal like the one you see above. Use balsa sticks. Now hold the model in front of a screen. Darken the room. Shine a light from a slide projector through the model against the screen. Hold the model in different positions and observe the different shadows. You can figure out the shape of an object from the shadows it casts.

In a similar way, scientists learn about the shapes of real crystals. Scientists use X rays. They study the reflections of the X rays, which bounce off the faces and edges of the crystals. They observe

○ **ADDITIONAL ACTIVITIES:**

Is water a part of any crystal? In ways that we don't understand, water is often combined with molecules of certain chemicals to form what are called *hydrates*. It is usually, however, the "dry" form whose name is changed. Thus, copper sulfate, the familiar blue crystal, is really a hydrated form to which five molecules of water are attached. The dry white powder that forms after heat has driven off the water is called "*anhydrous* (without water) copper sulfate."

As an experiment, dehydrate some crystals of copper sulfate, using a shallow dish, not a test tube. Add alcohol to the anhydrous copper sulfate. It turns blue, because water is present in the alcohol. The water combines with the anhydrous $CuSO_4$ to produce the blue $CuSO_4 \cdot 5\ H_2O$ (copper sulfate pentahydrate).

- *Of what use is this property of copper sulfate?* (It is a good test for water. If it is added to a clear liquid and no color change occurs, we know there is no water present in that liquid.)

Cobalt chloride ($CoCl_2 \cdot 6\ H_2O$—cobalt chloride hexahydrate) is pink or red. When heated to drive off the water, it becomes blue anhydrous cobalt chloride.

Make a pale solution of cobalt chloride in water. Let pupils use this as an ink and write a message on paper. It becomes practically invisible. Now heat (do not burn) the paper over a flame. The message becomes easily visible in blue.

Why does this happen? (The heat has driven off the water, converting the ink to anhydrous $CoCl_2$, which is blue.)

This chemical is used as a very rough "weather forecaster." A piece of paper dipped in the blue solution will lose its color when there is an increase of humidity in the air, presumably before rain. But it is unreliable, as we shall realize when we study the next unit, *Probing the Atmosphere* (see p. 232).

Background: This material will help you with the *Using What You Have Learned* section on page 188.

1. No. A "seed" crystal will grow only in a saturated solution of the same kind of salt. If pupils gently heat the ordinary salt solution, the crystal of potassium alum will dissolve.

2. The paper shapes have regular geometric structures, like the crystalline shapes of solids.

3. The small pieces of salt have the same crystalline shape as the salt in rock form.

the patterns that the X rays cast on photographic film. The patterns made by different crystals help the scientist to know the shapes of the crystals.

When scientists learn more about how crystals are formed and how they take shape, they will know more about how matter is put together in the universe. Crystal shapes give clues to the structure of matter, because the molecules of matter join together only in certain ways. Now you can understand why the study of crystals is an important part of today's science.

Using What You Have Learned

1. Will a "seed" crystal of one substance grow in a solution that has been made from a different substance? For example, will a potassium alum seed grow in a solution of table salt? Experiment to see if this will happen.

2. Cut out about twenty squares of the same size from construction paper. Put them together on your desk to form a regular fixed shape. Now cut some rectangles, triangles, and other shapes, of various sizes, like those you see in the drawing. Can you fit these new shapes into your earlier fixed pattern? In what way are the paper shapes like the crystal shapes?

3. Get a large piece of rock salt. Break it up with a hammer. Examine the small pieces with a hand lens. How are these small pieces like the bigger piece?

4. The following chemicals can be used for crystal growing: ammonium dichromate, chromium potassium sulfate, cobalt chloride. Try growing crystals of these chemicals using each of the two ways described in this unit.

Elements, Atoms, and Molecules

You have learned that crystals have fixed shapes. Chemists study these fixed shapes very carefully to see how crystals are made. By studying crystals, scientists have learned that all matter is made of some very simple materials.

Elements

For thousands of years, many men believed that all substances are made of a few simple things put together in many different ways. A long time ago, people believed that everything was made of fire, air, earth, and water.

It is now known that everything in the universe is made of one or more of the more than one hundred different substances called **elements** (EL-uh-ments). A substance that cannot be broken down into other substances is an element. All substances we know about are either elements or combinations of elements.

The elements are like the letters of the alphabet. Letters can be put together to make thousands of different words—from *aardvark* to *zymurgy*. The elements can be arranged and rearranged to make the many different materials that we use every day. Everything is made of these elements in various combinations. The paper in the book you are reading, the chair on which you are sitting, and the fabric in the clothes you are wearing are all made of elements. Even *you* are made of many different combinations of elements.

Look at the list of some important elements on page 190. The symbols for the elements and some of the ways in which these elements are found in nature or are used by men are also listed. A chemical symbol usually consists of the first one or two letters of the name of the element. (Some symbols come from the Latin names of elements.) Chemists use these symbols to stand for the various elements. It takes less time and space to write the symbol than to write the full name of the element.

Hydrogen is the lightest element found in nature. Uranium is the heaviest. Several elements heavier than uranium have been made by scientists, but these elements last only for very short periods of time. Berkelium, lawrencium, and californium are examples of man-made heavy elements.

Nature is made up mostly of the light elements. In fact, hydrogen, the lightest element of all, makes up about 76 per cent of the universe. Helium, the next lightest element, and hydrogen

TEACHING SUGGESTIONS
(pp. 189–191)

LESSON: What are the basic particles studied by the chemist?

Background: The idea that all matter is composed of atoms—indestructible particles of matter that cannot be further subdivided—has its roots in early Greek philosophy. But Greek Atomism was a philosophical doctrine, neither derived from nor supported by observation. The first scientific atomic theory, based on observation and experiment, was that of John Dalton in 1803. Dalton specified certain atomic properties: Atoms of one *element* are alike in all respects (in particular, they have identical weights); atoms of different elements have different properties and different weights; a *compound* is composed of *molecules*. Dalton formulated the law of definite proportions and the law of multiple proportions dealing with the combining weights of atoms and molecules in elements and compounds.

In 1819 the Swedish chemist, J. J. Berzelius, suggested a system of notation, using symbols for the elements. The symbol is an abbreviation of the name of the chemical element—either the Latin name or the English name.

Learnings to Be Developed:

An element is the simplest form in which a substance can exist.

An element is composed of one or more atoms.

The atoms of an element give it unique properties.

Developing the Lesson: Give a brief history of the atomic theory as described in the "Background." It is very difficult for children to understand what an atom is. Ask them to imagine that they have a supermicroscope, which could magnify a hundred million times. Looking through the supermicroscope at their hands, they would see their skin made up of little balls. The balls would not all be the same size or shape. There would be about a dozen kinds of balls. Now if they look at a diamond, they would see little balls all the same size, shape, and kind. If the pupils could examine hundreds of objects with the supermicroscope, and list all the different kinds of atoms, they would find only about a hundred different kinds. Each kind of atom is called a chemical element, and it has been given a name and a symbol.

Refer to the chart, "Some Important Elements," on page 190 and have the pupils add to the "Found In" column. Suggest that

Some Important Elements

Element	Symbol	Found In
ALUMINUM	Al	airplane parts, kitchenware
BROMINE	Br	medicines
CALCIUM	Ca	chalk, bones of the body, teeth
CARBON	C	all living things
CHLORINE	Cl	poisons used to kill germs
CHROMIUM	Cr	plated automobile parts
COPPER	Cu	wire
GOLD	Au	jewelry
HELIUM	He	lighter-than-air craft
HYDROGEN	H	water
IODINE	I	poisons used to kill germs
IRON	Fe	steel
LEAD	Pb	paint, plumbing
MERCURY	Hg	thermometers
NICKEL	Ni	batteries
NITROGEN	N	meat, cheese
OXYGEN	O	all living things
POTASSIUM	K	fertilizers
SILICON	Si	sand, glass
SILVER	Ag	jewelry
SODIUM	Na	table salt
SULFUR	S	insecticide, medicines
URANIUM	U	nuclear-power plants

make up about 99 per cent of the universe. The other hundred or so elements make up only about 1 per cent of all the matter that exists. Most of the matter in the universe is in the stars, and stars are made almost entirely of hydrogen and helium. The elements found most often in the solid parts of the planet earth are silicon and oxygen. After these, the next most plentiful elements are aluminum and iron.

Collect some of the elements in the list on page 190. Bromine, chlorine, calcium, hydrogen, iodine, potassium, and sodium are difficult to get and can be very dangerous. But you should be able to find some of the others, like iron and aluminum. Discover what you can about their properties. Are they solid, liquid, or gas at room temperature? Soft or hard? What colors are they?

Atoms

For hundreds of years, scientists tried to discover the building blocks of the substances in the universe. They tried to find out if all elements are made of the same units. They discovered that, if you took any substance and broke it into tiny pieces, you would finally get a tiny piece that could not be divided. Today, scientists know a great deal about that tiny piece of matter. The smallest piece of any kind of matter is called an **atom.** *Atom,* from ancient Greek, means "not able to be cut."

Atoms are so small that no one can see them. Scientists have only been able to make a *model* of an atom. They use the model to explain how an atom must look for the scientist to be able to predict accurately what the atom will do. Scientists have done experiments to tell whether or not their model is useful. They have changed this model from time to time as new discoveries have been made about the atom. The model you will read about in this unit was developed after years of experimenting.

The atoms of each element are different from the atoms of every other element. There are over one hundred elements. Each element has its own kind of atom, but all atoms are made of the same parts—electrons, protons, and neutrons—in various combinations. Atoms are the building blocks of all the matter in the universe.

Molecules

Atoms combine to make up every substance in the universe. When atoms combine, they form a **molecule.**

An atom may combine with another atom of the same type to form a molecule of an element. For example, two

they use information found on the containers of cereals, food, and medicines, as well as information from their own experience. Some possible additions might be:

Al: A good conductor of electricity, it is used therefore in electric transmission lines. Alum is used in water purification. It is also found in buffered aspirin.

Br: Combined with silver, it is used in photography. The dye industry uses large amounts. It is also found in ethyl gasoline and tear gas.

Ca: Plaster of paris and cement.

C: Diamond, graphite, coal, gasoline, and carbonated soda.

Cl: Table salt, laundry bleach, and chloroform.

Cr: Paint pigments, stainless steel cutlery, and resistance wires on toasters.

Cu: Copper salts are poisonous. The copper sulfate used in a previous experiment is an algacide.

Ask pupils to name elements not listed in the table. This should be done without reference of any sort. It would be expected that most children could supply: fluorine, F; helium, He; magnesium, Mg; neon, Ne; phosphorus, P; platinum, Pt; radium, Ra; tin, Sn; tungsten, W; and zinc, Zn.

TEACHING SUGGESTIONS
(pp. 192–193)

LESSON: What is a molecule?

Background: A molecule, made up of two or more atoms, is the smallest unit of a compound.

It is advisable to keep your thinking along the lines of the idea that all matter is molecular in nature, but not all matter is composed of molecules.

The distinction may be too academic for the children at this stage, but you should be forearmed for the "bright" child.

Learnings to Be Developed:

Atoms combine to form molecules.

A compound is composed of one or more molecules.

Developing the Lesson: Discuss the text beginning on page 191 and explain the diagrams on page 192. The major concept to emphasize here is the meaning of compound. The experiment on page 193 should be the culmination of this lesson and should emphasize compound formation when heat is added. The compound is iron sulfide.

Some precautions are in order. In Step 5: Heat gently at first, then

hydrogen atoms form a molecule of hydrogen. Using circles and the symbol for hydrogen, we can easily show the combinations:

$$\mathrm{H} + \mathrm{H} \rightarrow \mathrm{H\ H}$$

Chemists write the combination this way:

$$\mathrm{H} + \mathrm{H} \rightarrow \mathrm{H_2}$$

Oxygen atoms also combine, and form an oxygen molecule:

$$\mathrm{O} + \mathrm{O} \rightarrow \mathrm{O\ O}$$

$$\mathrm{O} + \mathrm{O} \rightarrow \mathrm{O_2}$$

A nitrogen molecule is formed in the same way.

$$\mathrm{N} + \mathrm{N} \rightarrow \mathrm{N\ N}$$

$$\mathrm{N} + \mathrm{N} \rightarrow \mathrm{N_2}$$

The atoms of hydrogen, oxygen, and nitrogen usually are found in pairs. Each pair is a molecule of that element. A molecule of an element contains only one kind of atom.

Atoms also combine with different kinds of atoms to form molecules. When two or more *different* kinds of atoms combine in a molecule, they form a **compound** (KOM-pownd).

$$\mathrm{Na} + \mathrm{Cl} \rightarrow \mathrm{NaCl}$$

Na = atom of sodium

Cl = atom of chlorine

NaCl = molecule of sodium chloride (table salt)—a compound

$$\mathrm{C} + \mathrm{O} \rightarrow \mathrm{CO}$$

C = atom of carbon

O = atom of oxygen

CO = molecule of carbon monoxide—a compound

What Happens When Elements Combine?

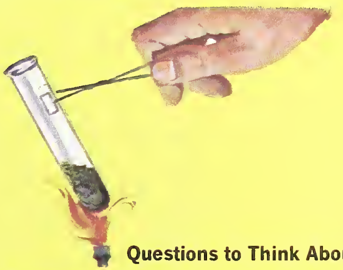
(This should be done only by the teacher.)

What You Will Need

sulfur	magnet	large pyrex
iron filings	source of heat	test tube

How You Can Find Out

1. Use the magnet to test both the iron and the sulfur.
2. Examine both the iron and the sulfur, and write down their properties.
3. Mix the iron and the sulfur together, and test the mixture with the magnet.
4. Fill the test tube one-quarter full with the mixture of iron and sulfur.
5. Heat the test tube for about three minutes in a hot flame. **Do not breathe the vapors! Do not point the test tube at anyone!**
6. Cool the test tube and remove the remaining substance.
7. Test the substance with a magnet, and write down its properties.



Questions to Think About

1. What were the properties of iron and sulfur before heating?
2. Were these properties changed when the iron and sulfur were mixed?
3. What happened when the mixture was heated?
4. What reasons can be given for the change after heating?

heat tube evenly until there is a red glow. In Step 6: After the test tube is cooled, wrap it in cloth and break it with a hammer to remove the new substance.

Have the pupils describe the physical properties of the new substance (dark brown or black lumps, nonmagnetic, etc.). These properties are quite different from those of the two original substances. Therefore, a chemical change must have occurred, and a new substance—a compound—was formed.

$$Fe + S \longrightarrow FeS \text{ (iron sulfide)}$$

Background: Answers to the *Questions to Think About* are:

1. The iron was magnetic and the sulfur was yellow.

2. Before heating, the iron and sulfur retained their original properties when mixed. The energy for a chemical change was supplied by the heat. All change required energy in some form.

3. The iron sulfide did not exhibit the properties of iron or sulfur.

4. Heat energy was put into the system in order to allow the two elements to combine—to force the atoms of each substance into a new relationship or compound.

TEACHING SUGGESTIONS
(pp. 194–195)

LESSON: What information does a chemical formula give?

Background: A symbol stands for one atom of an element.

A subscript placed after and slightly below a symbol indicates that there is more than one atom of the element. The number of atoms equals the numerical value of the subscript. When a subscript is not written after a symbol, it is understood that the subscript is 1.

Cl_2 means 2 atoms of chlorine. H_2O means 2 atoms of hydrogen and one atom of oxygen. However, H_2O_2 is an entirely different substance since it has two atoms of hydrogen and two atoms of oxygen.

CO has 1 carbon atom and 1 oxygen atom but is not the same substance as CO_2, which has 1 carbon atom and 2 oxygen atoms.

Avoid using the formula for any ionic compound such as a salt. The formula indicates a ratio of ions in the crystal lattice, not the formula for a single molecule. Limit examples to formulas for gases or molecular compounds such as benzene (C_6H_6), methane (CH_4), or octane (C_8H_{18}).

Chemical Formulas

Scientists have given every substance a **formula** (FOR-myoo-luh). The formula serves as a sort of recipe, which tells what kinds of atoms the substance is made of and how many atoms there are in a molecule of the substance. A molecule of table salt contains one atom of sodium combined with one atom of chlorine. Its formula is NaCl. A molecule of the oxygen gas you breathe has two atoms of oxygen. The formula for oxygen gas is O_2. A molecule of carbon monoxide has one atom of carbon and one atom of oxygen. The chemist writes the formula for carbon monoxide as CO.

In many compounds, an atom of one element does not combine with only one atom of another element. For example, two atoms of hydrogen will combine with one of oxygen to form a molecule of water. The formula for water is H_2O. Two atoms of oxygen combine with one atom of carbon to form carbon dioxide, CO_2. Three atoms of hydrogen combine with one atom of nitrogen to form a molecule of ammonia gas, NH_3.

Look below at the formulas for common compounds. By referring to the symbols of the elements on page 190, you can tell what elements are in each of the compounds. You also can tell from the formula how many atoms of each element are in a molecule of each compound.

The chemist must know what elements are found in many different compounds. Only then can the chemist know how to use the compounds and predict what will happen when they are mixed with other compounds. For example, baking soda has the formula $NaHCO_3$, and acetic acid, found in vinegar, has the formula $HC_2H_3O_2$.

Formula	Substance
$C_{12}H_{22}O_{11}$	table sugar
H_2O_2	hydrogen peroxide
SiO_2	sand, silicon dioxide
$CaCO_3$	chalk, calcium carbonate
Fe_2O_3	rust, iron oxide
CCl_4	carbon tetrachloride

You can see what happens when these two substances are put together. Put about one-half teaspoonful of baking soda into an empty jar. Add one or two ounces of vinegar. Bubbles form immediately. This means that baking soda and vinegar react to produce a gas. What gas is it? How would you find out?

You can find out what gas it is by observing its properties. This is what the chemist does. Look at the formulas of the substances which you have used. Can the gas contain nitrogen, argon, chlorine, or helium? There is no N or A or Cl or He in either baking soda or acetic acid. But there are some oxygen atoms, O, and some hydrogen atoms, H,

Properties of Common Substances

Substance	Formula	Properties
HYDROGEN	H_2	Gas at room temperature; lighter than air; explosive; odorless; colorless.
OXYGEN	O_2	Gas at room temperature; slightly heavier than air; supports burning; odorless; colorless.
WATER	H_2O	Liquid at room temperature; odorless; colorless.
CARBON DIOXIDE	CO_2	Gas at room temperature; heavier than air; smothers flames; odorless; colorless.
CARBON MONOXIDE	CO	Gas at room temperature; about the same weight as air; burns in air; colorless.

Learnings to Be Developed:

Atoms combine to form compounds in definite proportions.

Formulas express the elements and their proportions in the compound.

Developing the Lesson: After pupils read the text (pp. 194–196), have them write out the formulas on page 194 in "longhand." The following is an example of the pattern of responses that should be expected: The formula $Al(NO_3)_3$ indicates 1 aluminum atom, 3 nitrogen atoms, and 3×3, or 9, oxygen atoms.

Coefficients are usually found in an equation, which is a chemical shorthand for expressing the amount and kinds of combining materials and products formed during a chemical action.

2 CO means 2 carbon and 2 oxygen atoms. 2 CO_2 means 2 carbon and 2×2, or 4, oxygen atoms.

$2\ HgO \longrightarrow 2\ Hg + O_2$ states that two groups, each consisting of 1 mercury atom and 1 oxygen atom form (decompose) 2 mercury atoms and 2 oxygen atoms. The different kinds of atom are no longer chemically combined.

TEACHING SUGGESTIONS
(pp. 196–197)

LESSON: Can chemical changes be reversed?

Background: Tarnishing is a process whereby the surface of silver combines with oxygen to form an oxide of silver (a compound). This experiment is meant to show that the oxygen can be removed from the compound. In other words, the process *is* reversible.

Another experiment, such as the following, could be performed or else used in place of the one presented.

Limestone or marble chips (calcium carbonate, $CaCO_3$) are insoluble in water. Demonstrate.

Heat several pieces very strongly on a wire gauze or asbestos pad until they decompose into white to grayish lumps of powder.

$CaCO_3 \xrightarrow[825° C.]{} CaO$ (quicklime) $+ CO_2$

After the quicklime has cooled, put some into a beaker of water that has previously been tested with red litmus paper. (No change; water is neutral to litmus.)

Stir briskly to dissolve as much as possible. Note that its solution is accompanied by much heat.

present. The gas could be either a combination of both or a combination of one with some other element. What would you do to find out?

The table on page 195 shows some of these possibilities. Compare the properties of the gas obtained with those of the gases in the table. Which is it?

Note that the properties of compounds are not the same as the properties of the elements of which the compounds are made. The element carbon is usually a black solid that burns readily. Coal is mostly carbon. Oxygen is a colorless gas that enables burning to take place. Yet carbon dioxide is a colorless gas that does not burn. Hydrogen is a highly inflammable gas. Oxygen enables burning to take place. But water, a compound of these two gases, is a liquid used to fight fires.

When two or more elements combine to form a compound, no atoms are lost or added. There are as many atoms in the compound iron oxide as in its elements, iron and oxygen. Scientists can measure the substances to prove this. In a compound the atoms are rearranged, but their number stays the same.

The Structure of Atoms

Have you ever dragged your feet across a thick rug and then touched a metal object? Did you get a shock? This is an example of static electricity.

You can make static electricity in another way. Rub your comb with a piece of wool. Touch the comb to a pile of tiny pieces of paper. What happens? Does the comb attract some papers? Rub a balloon against your sweater. Is the balloon then attracted to the wall or ceiling?

In each of these experiments, you discover something about a property of matter. All substances have *positive* and *negative* charges. Ordinarily, every substance is *neutral*. That is, it has as many positive charges as negative charges. They neutralize each other. Right now, your desk is electrically neutral. The book you are reading, your chair, your pencil, and the flag in your room are also neutral.

Scientists have concluded from static electricity experiments and other experiments that every atom is made up of particles, most of which are charged. Scientists have decided this on the basis of their experiments, though no one has ever seen an atom or its particles.

Look at the model of the hydrogen atom on page 199. It is the simplest of the over one hundred different kinds of atoms. In the center of the atom is a **nucleus.** The nucleus is made up of one

Can Chemical Changes Be Reversed?

What You Will Need

a piece of aluminum foil	½ teaspoonful of table salt
1 tarnished silver object	½ teaspoonful of baking soda
1 small pan	source of heat
1 pint of water	

How You Can Find Out

1. Place the tarnished silver object on a piece of aluminum foil in the bottom of the pan.
2. Dissolve ½ teaspoonful of table salt and ½ teaspoonful of baking soda in 1 pint of water.
3. Add the solution to the pan with the silver object.
4. Boil the mixture until you see changes.

Questions to Think About

1. What changes did you see in the materials in the pan?
2. How can you explain these changes?
3. From this experiment can you tell what chemical change takes place on film when you take a photograph?

After the solution has cooled, filter it into a clean beaker and test with red litmus. (It will turn blue.)

$$CaO + HOH \rightarrow Ca(OH)_2$$
(limewater)

Have a pupil blow through a straw into the beaker. The solution will turn milky as a result of the addition of carbon dioxide.

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + HOH$$

(The process has been reversed.)

Let the pupil continue to blow until the solution is quite white. Let the solution settle for a while. (The calcium carbonate is insoluble in water.)

Answers to *Questions to Think About* on page 197:

1. The tarnish disappears from the spoon; a black film is deposited on the foil.

2. A chemical reaction takes place.

3. Light falls on the sensitive chemicals of the film. The film grains are changed by the light that hits them. After being developed and fixed, the changed grains show black. This is a negative of the original image. When light goes through the negative onto film, we now have a picture like the original image.

TEACHING SUGGESTIONS
(p. 198)

● **LESSON:** How can invisible objects be studied?

Background: This experiment illustrates a very important activity of scientists. They very often cannot see—directly or indirectly—the material with which they deal, but if they can develop a model that conforms to some of the knowledge they have about the material, study of that model can lead to new insights and new understandings, and, ultimately, to new discoveries and to new models that perform better.

The models of atoms and molecules that we will build in the next few lessons are not literal models (and this should be strongly impressed upon the class), but they conform to our experiences and explain and predict both physical and chemical properties that can be tested. For example, we cannot see the Fe atom or the S atom, nor can we see the FeS molecule. But we see the blackish lump of FeS. The models we construct of Fe and S satisfactorily explain FeS and so are useful models.

Objects other than the pencil and stopper can add more variety to the exploration.

OBSERVATION

How Can Invisible Objects Be Studied?

What You Will Need

pencil
partner
rubber stopper
cellophane tape
small box

How You Can Find Out

1. Do not tell your partner what you are putting into the box.
2. Place the stopper or the pencil in the box.
3. Tape the box closed.
4. Give the box to your partner and ask him to tell you what is in the box *without opening it*.
5. Tell your partner that he can shake the box, turn it over, or do whatever he wishes to identify the object inside.

Questions to Think About

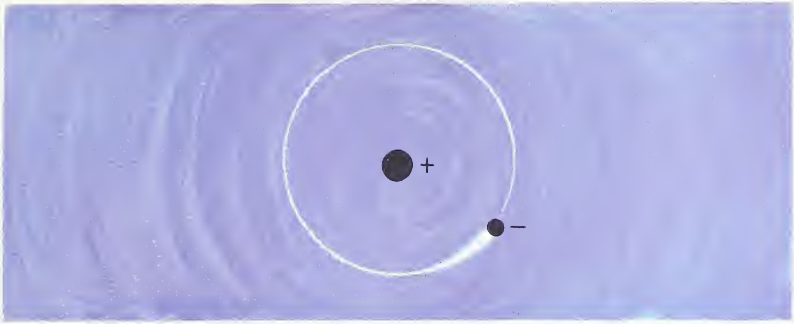
1. How does your partner's work resemble that of scientists?
2. Did your partner identify the object in the box?
3. How did he get his answer?

positively charged particle called a **proton** (PROH-ton). Notice in the diagram that a plus sign (+) is used for a positive charge.

Moving around the nucleus is one negatively charged particle called an **electron** (ih-LEK-tron). In the diagram a minus sign (−) is used for a negative charge. The electron moves in a path, or **orbit** (OR-bit), around the nucleus. The electron moves so rapidly that its position in orbit cannot be spotted exactly.

All other atoms have another kind of particle in the nucleus. This particle is called a **neutron** (NOO-tron). As you might guess from the name, the neutron is neutral. It has no electrical charge.

The hydrogen atom has exactly one positive charge and exactly one negative charge. The hydrogen atom is neutral. Most atoms are neutral. You will find that in most atoms the number of protons (positively charged) is equal to the number of electrons (negatively

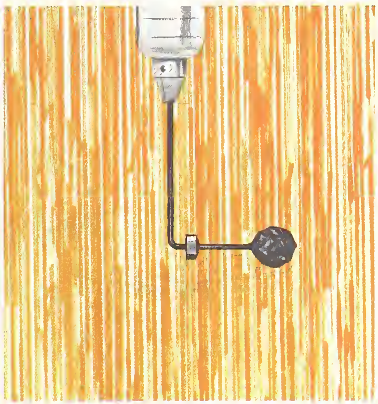


Hydrogen atom

charged). When the number of positive charges is equal to the number of negative charges, the total charge is zero.

This electrical balance can be upset. Some substances are electrically changed when they are rubbed. For example, the charges of a hard rubber comb, hair, many plastics, a balloon, and a wool sweater can all be changed. These substances become charged when they gain or lose electrons. If a substance gains electrons, it become negatively charged. If it loses electrons, it becomes positively charged.

For an idea of how the hydrogen atom might look, insert a long piece of baling wire into the bit socket of a hand drill. Bend the wire into an L-shape, as you see in the drawing. Slip a bolt onto the corner of the L to stand for a proton. Make a small ball from metal foil and stick it on the end of the wire. The foil ball stands for an electron. Spin the "atom." Do you see a blur where the electron is spinning?



TEACHING SUGGESTIONS
(pp. 199–201)

LESSON: How do chemists describe the structure of the atom?

Background: The model we used is based on the one suggested by Niels Bohr. Its presentation here is justified by its simplicity.

Stress that the Bohr atom is only one method of trying to picture an atom and that there are other models for use by chemists. If pupils take chemistry later on, they will learn the details of some other models.

The Bohr model has been proved only as far as the hydrogen atom is concerned.

The Bohr model serves quite well to illustrate atomic number, atomic weight, the principal valences, and many chemical combinations of the first twenty elements.

Atoms occur singly as the smallest particles of an element that can exist and still retain the physical and chemical properties of the element.

An atom consists of a nucleus around which one or more electrons may be found.

An atom can be considered to be mostly empty space.

For most practical purposes, the entire mass of an atom may be considered to be in the nucleus.

The atomic weight of an atom is a relative weight in comparison to the weight of an arbitrary standard. (Atomic weight is more properly called *atomic mass*.)

One standard is the 12.00000 units taken as the weight (mass) of the carbon 12 isotope. Chemists and physicists use this standard.

Another standard is the mass number, which is based on the sum of the nucleons (protons and neutrons), each with a mass of one unit. Nuclear scientists use the mass-number standard.

Learnings to Be Developed:

Atoms are made up of particles that have positive and negative charges.

These particles are called protons and electrons.

Properties of an atom are determined by the number of electrons and protons it contains.

In this model of the atom, the electron travels in a path you can see. In a real atom, the place where the electron is located would appear as a blur because the electron travels so fast. The hydrogen electron orbits the nucleus at least 7 million billion times a second!

Orbits of Particles in Atoms

Here are diagrams of helium and lithium atoms. Helium has two protons and two neutrons in the nucleus. It has two electrons in an orbit around the nucleus. Lithium has three protons and four neutrons in the nucleus. Three electrons circle the nucleus.

Notice that one of the lithium electrons has a longer orbit than the other two. Most atoms have several orbits and only a certain number of electrons can fit into any one of them. The orbit nearest the nucleus in any atom holds no more than 2 electrons. The next orbit holds no more than 8. The third orbit holds no more than 18. The fourth orbit holds no more than 32. Usually the inner orbits fill with electrons before the outer orbits.

Oxygen contains 8 protons and 8 neutrons in the nucleus. It has a total of 8 electrons: 2 in the first orbit and 6 in the second.

Atomic Mass

The **atomic mass** is the total number of particles in the *nucleus* of the atom. To find the mass number of an atom, add the number of protons and neutrons.

Thus, hydrogen has a mass number of 1 (1 proton, no neutron); helium has a mass number of 4 (2 protons + 2 neutrons = 4).

The mass number of lithium is 7 (3 protons + 4 neutrons = 7).

Helium atom

Lithium atom

Atomic Mass

Element	Symbol	Protons	Neutrons	Electrons	Mass Number
HYDROGEN	H	1	0	1	1
HELIUM	He	2	2	2	4
LITHIUM	Li	3	4	3	7
BERYLLIUM	Be	4	5	4	9
BORON	B	5	6	5	11
CARBON	C	6	6	6	12
NITROGEN	N	7	7	7	14
OXYGEN	O	8	8	8	16
FLUORINE	F	9	10	9	19
NEON	Ne	10	10	10	20
SODIUM	Na	11	12	11	23
MAGNESIUM	Mg	12	12	12	24
ALUMINUM	Al	13	14	13	27
SILICON	Si	14	14	14	28
PHOSPHORUS	P	15	16	15	31

Since each element has a different number of particles in its atomic nucleus, each element has a *different* mass number.

Above is a list of the first fifteen elements. It shows the number of protons, neutrons, and electrons in each of their atoms. The mass numbers of these elements are also shown.

You know that a proton has a positive charge and an electron has a negative charge. But remember that most atoms are neutral. Helium has 2 protons, and it also has 2 electrons. The atom has no

Developing the Lesson: Provide each pupil with a 1-foot square of white construction paper or cardboard. On this, have them draw four concentric circles with diameters of 4″, 5″, 6″, and 7″. The inner circle will represent the nucleus of an atom and the outer circles will represent electron orbits.

Provide each pupil with a number of little disks, about the size of thumb tacks, in 3 different colors, or have them cut out the disks from colored construction paper. The colors will represent protons, neutrons, and electrons.

Review with the class: the nucleus contains protons and neutrons, often referred to collectively as nucleons. The orbits or outer rings or shells contain only electrons; the first ring or shell can hold a maximum of 2 electrons (or is complete when it contains 2 electrons), the second ring or shell a maximum of 8 electrons, the third a maximum of 18 electrons, the fourth a maximum of 32 electrons. These orbits or shells are designated by the letters K, L, M, N, etc., the K shell being the shell nearest the nucleus, and so on.

Using the chart "Atomic Mass," on page 201, have the class construct, at your direction, atomic models of the various elements.

TEACHING SUGGESTIONS
(p. 202)

LESSON: Do properties change when elements combine to form compounds?

Background: The answers to the *Questions to Think About* are:

1. Have them write the chemical shorthand in "longhand."

2. All those listed as solutions are soluble. Ferric sulfate is the least soluble of these. Iron and copper filings are not soluble.

3. From their atomic structure, which absorbs some light waves and reflects the ones we see.

4. Blue and bluish green are the usual colors associated with copper compounds.

5. Red and red-orange are the usual colors of iron compounds.

6. From the experiment not too many property changes can be observed. Most answers would have to be based on prior knowledge or further testing.

7. Sodium generates tremendous heat and releases hydrogen when placed in water. The usual result is an explosion. Sodium in salt is safe when dropped in water. Compounds usually have properties different from their elements.

EXPERIMENT

Do Properties Change When Elements Combine to Form Compounds?

What You Will Need

copper filings	copper chloride solution, $CuCl_2$
iron filings	ferric chloride solution, $FeCl_3$
copper sulfate solution, $CuSO_4$	ferric sulfate solution, $Fe_2(SO_4)_3$

How You Can Find Out

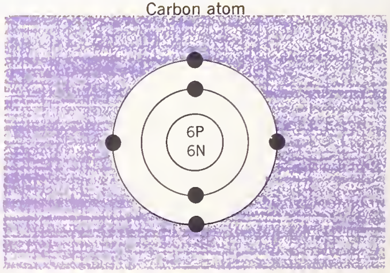
1. Examine the color of each substance.
2. How would these substances be grouped according to their colors?
3. Mix each substance with water.

Questions to Think About

1. What elements are in each of these substances?
2. Which substances dissolve in water?
3. How do the solutions get their colors?
4. Is there a difference in color between copper and its compounds?
5. Is there a difference in color between iron and its compounds?
6. Are there other properties of these elements which changed when they formed these compounds?
7. How can you determine if other elements behave in the same ways?

charge. On this page, you see a carbon atom. It has 6 protons and 6 electrons. The carbon atom is neutral.

Carbon atom



Ions

The top diagrams on page 203 show two neutral atoms—one of sodium, the other of chlorine. Notice that sodium has one electron in the outer orbit and

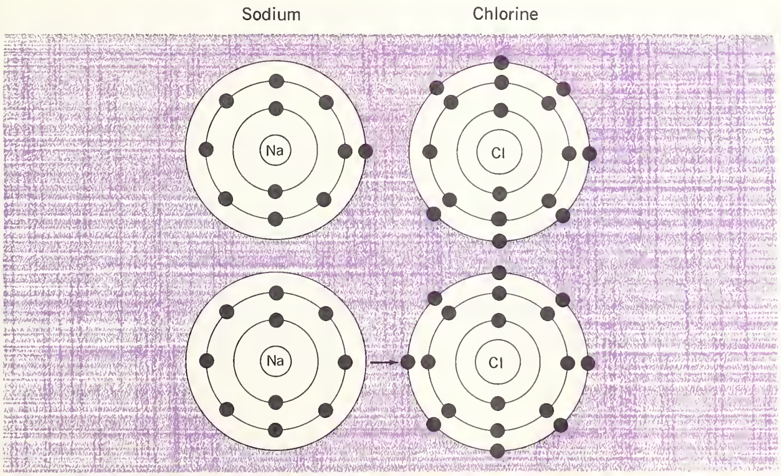
chlorine has seven. When sodium and chlorine atoms come together, the single electron in the outer orbit of the sodium jumps to the outer orbit of the chlorine atom. A chemical reaction produces sodium chloride.

When the single electron jumps from the sodium atom to the chlorine atom, the sodium atom is left with an extra proton. Therefore, the sodium atom now has a positive charge. But the chlorine atom has an extra electron. It now has a negative charge. Since unlike charges attract each other, we can therefore expect that the sodium and chlorine will be attracted to each other.

Atoms that have lost or gained electrons are no longer neutral. Such atoms are called **ions** (EYE-unz). The ions of sodium and chlorine are held together strongly because when they meet they have opposite charges. The atoms become ions.

When elements combine to form compounds, or compounds combine with other compounds, the activity usually takes place among electrons in the outer orbits of the atoms.

When a chemist knows the structure of an atom, particularly the number of electrons in the outer orbit, he can usually tell how the element will combine with other elements. For example, fluorine has seven electrons in the outer orbit. Chlorine also has seven electrons. These elements are not likely to combine with one another. On the other hand, with the same number of electrons in the outer orbit, fluorine and chlorine have similar properties. They



TEACHING SUGGESTIONS
(pp. 203–204)

LESSON: What are ions?

Background: The two most commonly encountered solid types are molecular solids and ionic solids. Sugar, carbon dioxide, and water are molecular solids; sodium chloride, calcium nitrate, and barium chloride are ionic solids.

In the solid state, ionic solids are composed of ions of opposite charge bound in a rigid and regular structure known as an *ionic crystal lattice*. Such a structure is diagramed at the bottom of page 204. It is common table salt and has a cubic organization. Every chlorine ion is surrounded on the three axes by six positive sodium ions.

Learnings to Be Developed:

In some crystals, ions are held together by electric charges.

An ion is an electrically unbalanced particle.

Developing the Lesson: Use the models developed on pages 200 and 201 of the teachers' notes. Ask the class to unite the atoms of Na with those of Cl. (Group the class in fours if possible, so that each pupil's model can represent one of the atoms in question.)

Ask the class to unite Na with F.

Ask the class to unite H with O. The 6 electrons of oxygen on the L shell are arranged so that the two missing spaces are at opposite sides of the nucleus, so that the molecule will be arranged in space to look something like H O H. This organization makes it possible to envision the OH radical attracted to Na, for example, in sodium hydroxide (NaOH), which is lye, or to have two OH^- ions attach themselves to one Ca^{++} ion, as in $Ca(OH)_2$, which is limewater.

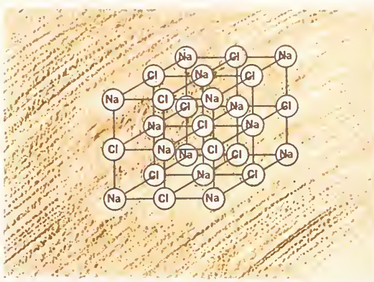
Have a number of pupils, representing equal numbers of Na^+ ions and Cl^- ions, arrange their cardboards to form a crystal of NaCl. Remind the class that electrical attraction holds the ions in the crystal form. Remind them that the electron shell represents a cloud or smear, that the electron is moving so quickly (on the order of several hundred billion revolutions per second) that the electrical attraction operates throughout the shell, not merely at the point where we place the electron. Therefore, a Cl^- ion can be surrounded by and attracted to many Na^+ ions at the same time that these Na^+ ions are themselves surrounded by and attracted to many Cl^- ions, thus building up a crystal.

both combine readily with hydrogen and with sodium. Fluorine and chlorine are considered to be in the same family of elements because of their similar properties.

Ions and Crystals

Knowing about ions should help you to understand how crystals grow. You remember that a "seed" crystal was hung in a salt solution. When salts are added to water, a great deal of electrical activity immediately begins. Salt crystals are made up of electrically charged atoms, or ions. The ions are held together by electrical forces. Water weakens these forces and frees the ions. A single ion will gather water molecules around it.

How would you describe this crystal shape? Can you tell the order in the structure of this crystal? You can make a model of the crystal using gumdrops and toothpicks. Why would such a model show you the structure of the crystal better than the drawing does?

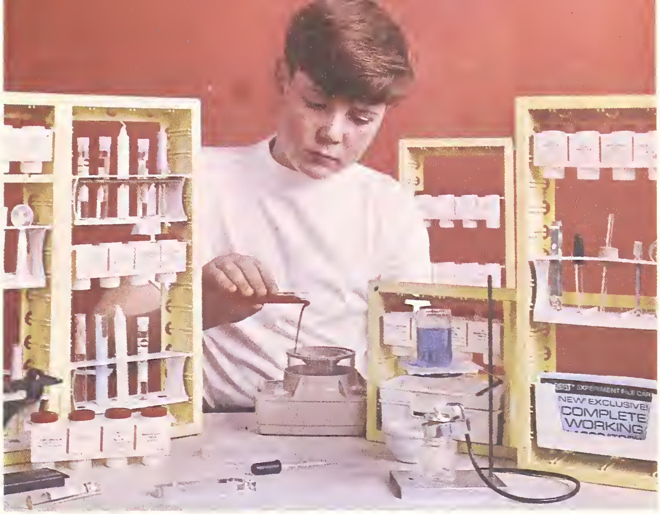


The ion is "clothed" in water molecules. When this happens, the salt ion is *dissolved* in water.

When a seed crystal is placed in a saturated solution, each ion with its surrounding water molecules may be attracted to the surface of the crystal. Where each ion, and its surrounding water molecules, goes depends upon the order of the atoms already present in the seed. Study the model of sodium chloride on the left and note how each ion has found its place in the crystal structure after losing its coat of water molecules. Note the order in the structure of this cubic crystal. Ions will continue to be deposited upon the seed in this orderly fashion until there are no more ions available.

Your Use of Chemistry

Perhaps you will make a hobby of the study of chemistry. As you have seen in this unit, there are many experiments you can try. Each one will help you to learn more about the substances that make up all of the things in the universe. When you learn about chemistry, you begin to see an order in the world of materials. Perhaps you will decide to become a chemist and discover more about the materials of which our world is made.



Using What You Have Learned

1. Draw pictures of the following atoms: neon, boron, nitrogen, aluminum, beryllium, fluorine.

2. Helium's outer orbit is "filled." It has two electrons. Do you think it combines readily with other elements? Does this make it useful for certain jobs?

3. What other elements on the list on page 190 have outer orbits which are "filled"?

4. An element has a mass number of 32. It has 16 neutrons. How many protons does it have? What is the element?

5. Read about the discovery of certain elements. Find out what the following scientists contributed to the discovery of elements: Marie Curie, Humphry Davy, Ernest O. Lawrence, Henry Cavendish, Antoine Lavoisier.

TEACHING SUGGESTIONS
(p. 205)

Background: The answers for *Using What You Have Learned* are:

1. Use information gathered from the chart on page 201.

2. No. It is called an *inert* gas, because it does not combine. Therefore, it is very useful in certain jobs where chemical reactions are not wanted. For example, it is used in blimps and balloons because there is no danger of fire (which is the combining of a substance with oxygen).

3. None. However, on page 201, neon has 8 + 2 electrons.

4. Such an element would have 32 − 16 or 16 protons. This would be the element following phosphorus. It is not on the chart on page 201. The element having 16 protons and a mass number of 32 is sulfur.

5. Marie Curie discovered polonium and radium in 1898. Humphry Davy discovered barium in 1808. Ernest O. Lawrence assisted in creating some elements with a higher atomic weight than that of uranium. Henry Cavendish discovered hydrogen in 1766. Antoine Lavoisier named oxygen but did not discover it.

TEACHING SUGGESTIONS
(pp. 206–207)

Background: These two pages constitute a review of the concepts and terminology introduced in this unit.

What You Have Learned: This is a summary of the entire unit, with new words in boldface type.

Checklist of Science Words: Remind the pupils that there is a *Dictionary of Science Words* on pages 358–364. They should consult this dictionary whenever they are unsure of the precise meaning of a word.

WHAT YOU KNOW ABOUT

The World of Chemistry

What You Have Learned

Chemists study the **chemical properties** and the **physical properties** of natural substances and man-made substances. They use **formulas** to tell the kinds and numbers of **atoms** in a substance.

Everything in the universe is made of just over one hundred different substances called **elements.** An element is a substance that cannot be broken down into other substances by ordinary means. The smallest piece of any element is called an atom. Atoms, either by themselves or combined with one another, make up every substance in the universe. When atoms combine, they form **molecules.** When atoms of more than one kind combine in a molecule, they form a **compound.**

In the center of each atom is a **nucleus.** The nucleus is made up of **protons** and **neutrons.** Moving around the nucleus are negatively charged particles called **electrons.** Atoms that have lost or gained electrons are called **ions.**

The **state of matter** of a substance may be solid, liquid, or gas. A **soluble** substance can dissolve in another substance and make a **solution.**

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

atom	electron	molecule	proton
atomic mass	element	neutron	saturation
crystal	ion	nucleus	solution

Complete the Sentence

Write the numbers 1 to 10 in your notebook. Next to each number, write the word or words that best complete the sentence.

1. A chemist begins a description of a substance by listing its ___?___.
2. The three states of matter are ___?___, ___?___, and ___?___.
3. If a substance dissolves in another substance, it is ___?___.
4. Substances which have a fixed shape are known as ___?___.
5. Everything in the universe is made of just over one hundred different substances called ___?___.
6. The smallest piece of any element is called an ___?___.
7. When atoms combine, they form a ___?___.
8. A kind of recipe that tells what kinds of atoms and how many are in a substance is called a ___?___.
9. A positively charged particle is called a ___?___.
10. Atoms that are no longer neutral because they have gained or lost electrons are called ___?___.

Which Is Which?

Which of the properties listed below are physical properties? Which are chemical properties? List the properties in your notebook and next to each write *physical* or *chemical*.

Ice melts at 32° F.
Salt dissolves in water.
Iron rusts when it combines with oxygen.
Sodium combines with chlorine to form sodium chloride.

Complete the Sentence:

1. properties
2. solid, liquid, gas
3. soluble
4. crystals
5. elements
6. atom
7. molecule
8. formula
9. proton
10. ions

Which Is Which?

Physical
Chemical
Chemical
Chemical

TEACHING SUGGESTIONS
(pp. 208–209)

Background: These pages reinforce the concepts presented in the unit by suggesting activities that extend the pupil's ability to apply the learnings derived from the unit.

What's the Word?

1. Solubility
2. Saturate
3. Crystal
4. Element
5. Formula
6. Molecule
7. Proton
8. Orbit

YOU CAN LEARN MORE ABOUT

The World of Chemistry

What's the Word?

1. An important physical property of any substance.
2. To combine as much of one substance as possible with another substance.
3. A substance with a fixed shape.
4. A substance that cannot be broken down into other substances.
5. A type of recipe used in chemistry.
6. A combination of elements.
7. A positively charged particle.
8. The path of an electron.

1	O			B					
2				R			E		
3	R				A				
4		E				T			
5					L				
6		M							
7P									
8		B							

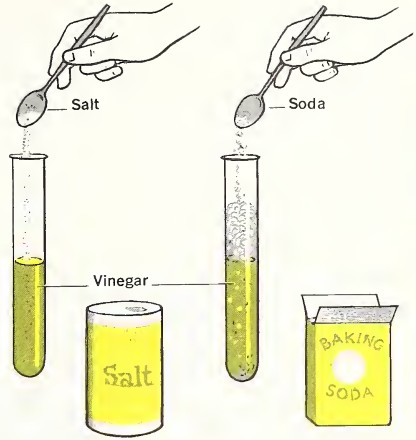
You Can Visit

A textile factory is a place where fabrics are made. Perhaps you can arrange to take a guided tour of such a factory.

Try to find out the chemicals that are used for dyes. Ask if there are scientists working for the factory. Find out what they do. Does the factory you visit make materials of dacron, rayon, or nylon? What are the advantages of these materials over wool and cotton?

Try This

Here is an experiment to show the difference between a physical and a chemical reaction. Add two teaspoonfuls of salt to a half full test tube of vinegar. What happens? Taste a tiny bit of the solution. How does it taste? Has any chemical reaction taken place? Now fill a test tube half-full of vinegar and this time add two teaspoonfuls of baking soda. What happens? What is forming? Do you see something being changed? Do you see something new being formed? Taste a tiny bit of the liquid in the test tube. Does it taste like vinegar or baking soda? What does the taste tell you? Can you explain what has occurred?



You Can Read

1. *The Story of Chemistry*, by Mae and Ira Freeman. You will read not only about the basic principles of chemistry but also about its applications.
2. *Exploring Chemistry*, by Roy A. Gallant. The history of chemistry from prehistoric times to today's frontiers.
3. *Antoine Lavoisier: Scientist and Citizen*, by Sarah R. Riedman. The life of "the father of modern chemistry."
4. *The Curies and Radium*, by Elizabeth Rubin. The story of this famous team and their work in studying radioactive elements.

Try This: Vinegar is an acid (acetic acid, $C_2H_4O_2$). Baking soda is sodium bicarbonate ($NaHCO_3$). This reaction is the basis for the soda-acid fire extinguishers (as distinct from the CO_2 foam extinguishers). Combining vinegar and baking soda causes the evolution of the gas carbon dioxide (CO_2). In the fire extinguisher, this gas forces the water out under pressure, and that is its sole function in this type of extinguisher. The water is the fire "fighter."

$$NaHCO_3 + C_2H_4O_2 \rightarrow NaC_2H_3O_2 + HOH + CO_2 \uparrow$$

Sodium acetate ($NaC_2H_3O_2$) is very soluble in water and will probably remain in solution.

KEY CONCEPTS

Key Concept 1. Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

Key Concept 4. All objects in the universe and all particles of matter are constantly in motion; man has discovered and stated the laws governing their motion.

Key Concept 5. The motion of particles helps to explain such phenomena as heat, light, electricity, magnetism, and chemical change.

Key Concept 6. There is a basic tendency toward stability or equilibrium in the universe; thus, energy and matter may be transformed, but the sum total of matter and energy is conserved.

Key Concept 9. The scientist has developed measures of space, time, and matter so that he can communicate explanations that are reproducible and make predictions about events in the natural environment.

CONCEPTS:

1. Weather takes place in the earth's atmosphere; heat and wa-

7

Other concepts appear under Learnings to Be Developed in each lesson found in the Teaching Suggestions.

Probing the Atmosphere

Air and Weather

Keeping Records of the Atmosphere

Weather Maps and Forecasting

ter produce changes in the atmosphere that result in changes in weather.
2. The earth's atmosphere may be divided into layers based upon the characteristics of the atmosphere at different altitudes.
3. Radiation from the sun heats the earth, and the earth heats the atmosphere.
4. Evidence regarding air temperature, relative humidity, wind speed and direction, and atmospheric pressure are used in describing and predicting weather.
5. Many methods are used in obtaining evidence regarding the atmosphere.

PROCESSES:

- Observing—Pages 212, 213, 214, 215, 216, 219, 220, 221, 224, 227, 228, 235, 237.
- Experimenting—215, 224, 225, 228.
- Comparing—213, 214, 215, 216, 219, 220, 221, 224, 225, 227, 228, 237, 239.
- Inferring—212, 213, 214, 215, 216, 219, 220, 221, 224, 225, 227, 228, 229, 235, 237, 239.
- Measuring—213, 220, 228, 234.
- Classifying—217, 218, 229, 230.
- Communicating—227.
- Demonstrating—213, 214, 216, 219, 225, 227, 235, 237.
- Explaining—212, 220, 227, 231, 235.
- Hypothesizing—216.

TEACHING SUGGESTIONS
(pp. 212–213)

Background: Weather can be defined in simple terms as the general condition of the atmosphere, or air, around us. Since air is a gas—strictly speaking, a mixture of gases—the concept of weather can be understood more readily if we review certain properties of gases. We owe our knowledge of these properties to the discoveries of such men as Robert Boyle, Jacques Charles, Joseph Gay-Lussac, and Thomas Graham, among others.

The properties of the atmosphere which are significant to our study of weather can be summarized as follows:

1. The volume of a gas decreases as the pressure increases.

2. The volume of a gas increases as the temperature increases.

From this knowledge the kinetic molecular theory of gases was formulated. This theory explains the characteristics of gases as follows:

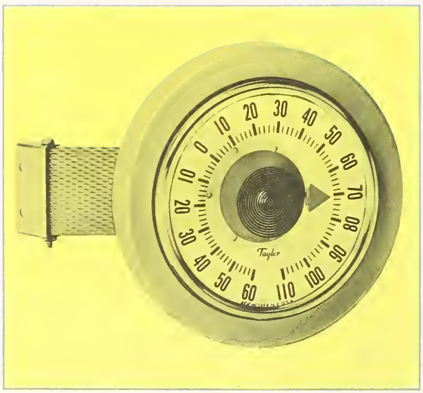
1. Gases are composed of molecules, which are separated by vast distances (relative to the sizes of the molecules) of empty space; in other words, gases are very porous.

The United States Weather Bureau now predicts the weather for thirty days in advance. In the future, it hopes to make three-month predictions. Behind each forecast is a vast amount of research. Space-age instruments are now helping scientists to find out how weather behaves and why it behaves as it does.

Air and Weather

The aims of weather scientists are to make accurate weather forecasts—short-range forecasts and long-range forecasts for a season and possibly for a year. To do this, scientists need a better understanding of what happens in the air.

Below is an outdoor thermometer. How does it differ from an indoor thermometer?



Air Can Be Heated or Cooled

Use an outdoor thermometer to take readings at 9:00 A.M., 1:00 P.M., and 3:00 P.M. Keep the thermometer in the shade. What does the thermometer measure? Are there differences in the readings? Why does the temperature of the air usually change during the day?

If you remember that the temperature of the air changes, then you will understand better how the weather forms.

In the experiment that follows some air in the soccer ball will flow out if you break the seal of the ball by putting a pin into the seal. Then the soccer ball will not weigh as much as it did before. Does the air in the ball have weight? The weight of the pail of sand will not change. The balancing stick will tilt downward toward the heavier object. How will you know that the air that escapes from the ball has weight?

Does Air Have Weight?

What You Will Need

yardstick	inflated soccer ball	pail
sand	pin from soccer ball	chair

How You Can Find Out

1. Suspend the soccer ball and the pail from the yardstick as in the diagram.
2. Keep adding sand to the pail until the soccer ball and the pail balance.

Questions to Think About

1. What can you assume when the soccer ball and the pail balance?
2. Now place the pin in the soccer ball. What happens to some of the air in the ball?
3. What happens to the yardstick? Can you explain why this happens?

2. The molecules are in rapid, random motion, colliding with one another without losing energy.

3. The rate of motion of gas molecules increases as the temperature increases (with heating, molecules acquire more energy).

Although the molecules of a gas are widely separated, a volume of gas still has weight. The weight of the individual molecules and the number of molecules in any given volume of gas determine the weight of that volume.

In the demonstration on these pages, the children will learn that air has weight by seeing that the pail of sand is heavier than the soccer ball after air has been let out of the ball.

TEACHING SUGGESTIONS
(pp. 214–215)

LESSON: How does an increase in temperature affect the density of a gas?

Background: The experiment with two air-filled bags has shown the children that lowering the temperature reduces the volume occupied by a given number of molecules of air. Conversely, the same volume of air at the colder temperature would contain a greater number of molecules. In this lesson the effect of increasing air temperature will be demonstrated.

Learnings to Be Developed: Heat produces changes in the atmosphere that result in changes in weather.

Developing the Lesson: Develop the children's understanding of the relation between density and the behavior of air molecules by using the following questions.

- *What does "density" mean?* (Weight per unit volume, which approximates number of molecules per unit volume.)
- *What is air?* (A mixture of gases.)
- *What is a gas?* (A mass of molecules in constant motion with vast distances between them.)

Shake the box containing ping-pong balls and golf balls. What do you observe?

The Density of Air Can Change

Take two plastic bags of the same size. Blow them up to the same size and tie each one tightly. Leave one bag in the classroom and put the other one in a freezer. The temperature there should be about 4° F. What happens to each of the bags?

The molecules in the bag with the warmer air move around very rapidly and take up more space. The air molecules in the bag of colder air move around less rapidly; they take up less space.

The activity illustrates a very important fact about weather: *a volume of cold air is denser than the same volume of warm air.* This means that cold-air molecules are closer together and have less space between them than do warm-air molecules.

Cool Air Pushes Warm Air Upward

A model will help you to understand why air rises when it gets warmer and why it falls when it gets cooler. Build a box with clear plastic or heavy celluloid sides. Make it about 1 foot long, 1 foot wide, and 10 inches high. Fill the box with ping-pong balls and golf balls. Marbles may be used if you cannot get golf balls. Shake the box with the ping-pong balls and golf balls roughly. Watch what happens.

Because the golf balls are heavier, they are pulled more by the earth's gravity. They move downward. The ping-pong balls are pulled less. Also, as they move downward the heavier golf balls force the ping-pong balls upward.

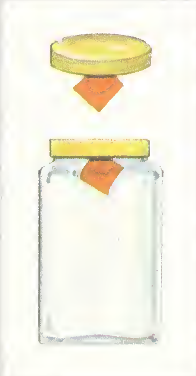
Pretend that each ping-pong ball is a warm-air molecule and that each golf ball is a cold-air molecule. The cold-air

EXPERIMENT

Which Can Hold More Water Vapor, Warm Air or Cold Air?

What You Will Need

2 jars of the same size, with lids
2 pieces of the same cloth, 1 by 2 inches
tape
thermometer



How You Can Find Out

1. Put one jar in the sunlight or on a warm radiator. Leave the other in a freezer. Do not put the lids on either jar.
2. After about half an hour, take the temperature of the air in each jar and record it.
3. Take the two pieces of cloth and wet them. Squeeze out as much water as you can from each. Suspend a piece of cloth from the lid of each jar with tape, as in the picture.
4. Return the cold jar to the freezer. Place the other jar back in the sunlight or on a warm radiator.

Questions to Think About

1. Which cloth dries first?
2. Can you tell why?
3. Which holds more water vapor, warm air or cold air?

molecules are closer together than the molecules of warm air. Cold air is denser than warm air. The cold air is pulled downward more than the warm air. The cold air hits against the warm air. The warmer air is forced upward just as the ping-pong balls were.

You can feel the air push. You can see the air move things. Moving air is called **wind.**

Water Vapor and Air

Water vapor is one of the gases found in air. The amount of water vapor in the air is not always the same.

If the jars in the experiment above are the same size, which jar holds more air? What happened to the water from the wet cloths? The molecules of water left the wet cloths and spread out into the air. We can say this another way.

- *What is the density of a gas?* (The number of molecules of a particular kind in a given volume.)
- *How can the density of a gas be changed?* (By changing the temperature or the pressure.)

To demonstrate you will need the following equipment: two beakers, two ring stands and two small rings, two round-bottomed flasks, two one-holed rubber stoppers, and two pieces of glass tubing.

Fill each beaker ²/₃ full of colored water. Insert a piece of glass tubing through each stopper and stopper each flask with most of the glass tubing outside the flask. Invert each flask through a ring and let the glass tube extend well into the colored water in the beaker below. Heat the air in one flask slowly.

- *What happens to the level of the liquid?* (It goes down.)
- *Why?* (The air in the flask is expanding; the rate of molecular movement is increasing, the distance between the molecules of the gas is increasing, and therefore the density of the gas is decreasing—that is, the number of molecules in a given volume is decreasing.)

TEACHING SUGGESTIONS
(pp. 216–217)

LESSON: What is the earth's atmosphere like?

Background: In general, the higher up one goes, the colder and thinner the air becomes.

Up to about 7 miles above sea level, the air does continue to get colder and reaches a minimum of −70° F. This layer of air up to 7 miles above the earth is the *troposphere,* in which the weather occurs. Between 7 and 35 miles above the earth, the temperature remains constant at −70° F. This layer of the atmosphere is the *stratosphere.*

Beyond the stratosphere are other layers of the atmosphere. Above the stratosphere is the *mesosphere.* In the mesosphere the temperature begins to increase again and reaches a maximum of about +20° F. at an altitude of 50 miles. The temperature declines again to −90° F. at about 50 miles above the ground, but then it begins to increase again with increasing altitude.

Above the mesosphere, at about 250 miles above the ground, is the *ionosphere.* In this level of the atmosphere the very thin layer of air is ionized by ultraviolet rays emitted from the sun.

The water was changed into water vapor. It **evaporated** into the air.

What was the temperature of the cold air? What was the temperature of the warm air? Did the cold or the warm air take up, or evaporate, water more easily? Did the same amount of water vapor get into the air in each jar? Because the molecules of cold air move slowly, more of these molecules fit into a jar. There is more space between the molecules of warmer air in the other jar. The molecules of water vapor fit between the molecules of warm air.

The wet cloth in the jar of warm air dried faster because the water evaporated faster. Water evaporates faster in air that is warm. There is more room between the molecules of warm air. Warm air is less dense than cold air.

Here is a summary of what you have learned about weather and air:

1. Weather takes place in the air.
2. The temperature of the air is always changing.
3. Because the air is made up of molecules, the air has weight.
4. The density of the air changes when the temperature of the air changes.
5. A given volume of cold air is denser than the same volume of warm air.
6. When cold air and warm air are next to one another, the cold air is pulled downward by gravity more than the warm air is. The warm air is forced upward by the cold air.
7. Water vapor is one of the gases in the air. Warm air can hold more water vapor than cold air can.

The Earth's Atmosphere

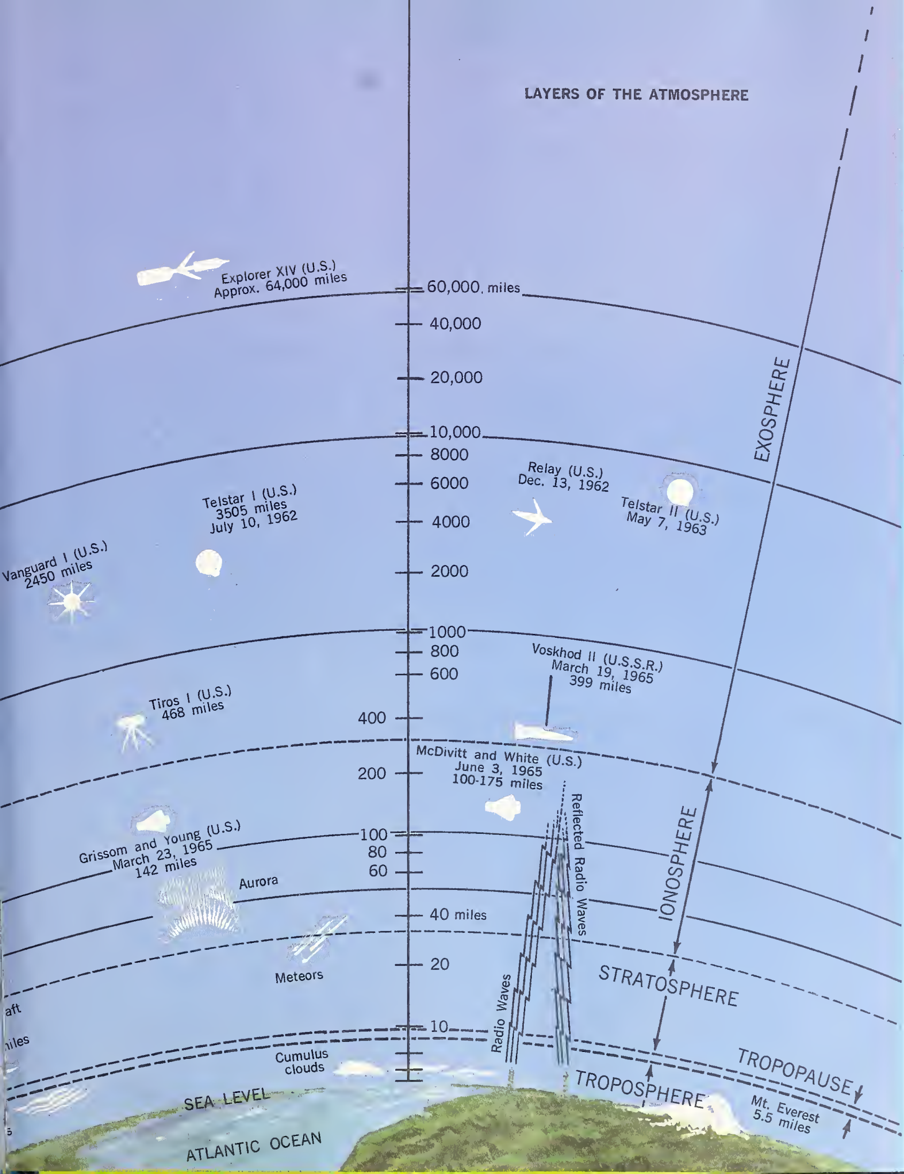
The total amount of air all around the earth is called the **atmosphere** (AT-muss-feer). The atmosphere is like a thick blanket of air around the earth. When you go 100 miles above the earth, there is almost no air.

You live in this blanket of air. The air is a mixture of gases. Most of the earth's air is nitrogen; the rest is oxygen, carbon dioxide, water vapor, and rare gases in small amounts.

The atmosphere is made up of different layers, as shown in the illustration.

Troposphere

The **troposphere** (TROHP-uh-sfeer) is the layer of the atmosphere nearest the earth. It is the part of the atmosphere in which weather takes place. Nearly all the clouds and winds are found in the troposphere. How far out from the earth does the troposphere go? Look at the picture for the answer.



Above the ionosphere is the exo*sphere*. This is the outermost layer of the atmosphere. The air is extremely thin and bombarded heavily by radiations from the sun.

Why does the temperature increase the higher one goes? This is because of the way that temperature is defined. If you will remember, temperature is defined as the motion of molecules. The faster molecules move, the higher the temperature. Since in the thin air of the upper atmosphere there is very little to hinder the motion of molecules of air, their movement is swifter, and, therefore, the temperature is higher.

Learnings to Be Developed:

All of the air around the earth is called the *atmosphere*.

The atmosphere is made up of layers.

Developing the Lesson: Ask if any of the children have flown in a jet, to and from a distant city.

Which way took longer? (From east to west; for example, from New York to California.)

Why? (The jet stream aids the plane in moving from California to New York but hinders it in the other direction.)

TEACHING SUGGESTIONS
(pp. 218–219)

● **LESSON:** How does the sun's energy affect our atmosphere?

Background: In order to understand how the troposphere—the weather layer—is warmed by the earth's surface, we must understand what happens to the sun's rays as they hit different surfaces. The energy of the sun is brought to earth by the process of *radiation*. When the sun's rays hit surfaces, three things may happen, depending on the nature of the surface.

1. They may be *transmitted;* they may pass right through the surface virtually without loss of energy, as through glass. The glass remains the same temperature.

2. They may be *reflected;* that is, they may bounce off the surface and radiate back into the atmosphere. Most smooth, shiny surfaces are good reflectors. Mirrors, metal surfaces, snow, and water are examples of reflecting surfaces, which remain cool.

3. They may be *absorbed;* that is, they may penetrate the surface of the material, in which process they are changed into heat energy. The material becomes warm. The best absorbers are rough, dark surfaces such as soil and rock.

Tropopause

Above the troposphere, there is a narrow layer of air called the **tropopause** (TROHP-uh-pawz). The tropopause mixes a little with the layer above it and the layer below it.

Just below the tropopause in the troposphere are powerful wind currents called **jet streams.** They occur about 20,000 to 35,000 feet above the earth. Jet streams travel eastward and can spread out to about 50 to 300 miles wide. Their average speed is about 150 to 200 miles per hour. These jet streams are strongest at their centers, shift about, and vary in strength. Scientists believe that these winds are caused by differences in the temperatures among layers of the atmosphere.

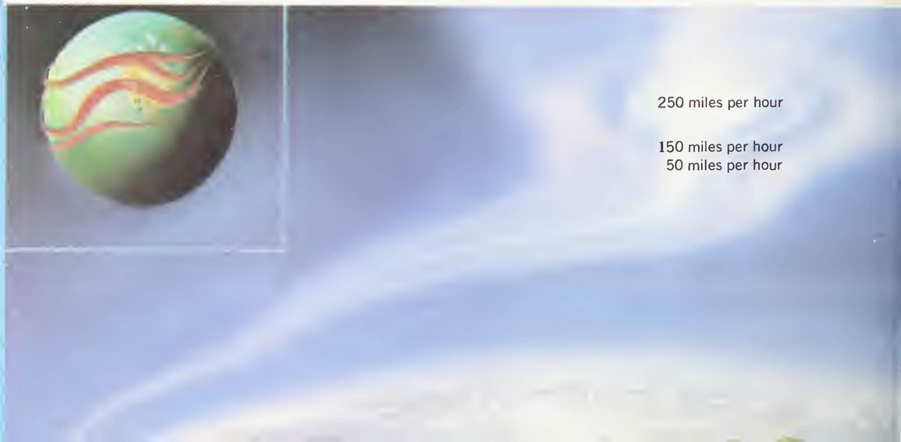
One jet stream is over the United States. Airplane pilots can sometimes make good use of this jet stream. You already know that the jet streams go from west to east. Is the jet stream more useful when flying from California to New York or the other way?

Stratosphere

The **stratosphere** (STRAT-uh-sfeer) is the layer of atmosphere in which there is almost no weather. There is very little upward air movement. Clouds are seldom found in the stratosphere. Jet pilots like to fly there because it is easy for them to see very far. Also, the lack of air currents makes the airplane ride very smooth. The air is so thin in the stratosphere that there is little friction

The winds are strongest in the center of the jet stream. The jet stream flows from west to east in a meandering path

Where are the winds strongest in the jet stream? What is the jet stream's direction?



against the plane. Because of this, less fuel is used. Do pilots have to worry about storms in the stratosphere?

Other Layers of the Atmosphere

The **ionosphere** (eye-ON-uh-sfeer) is above the stratosphere. The air in the ionosphere is very thin. The molecules are very far apart. The **exosphere** (EK-suh-sfeer) is the highest layer of the earth's atmosphere. In this layer the air molecules are very far apart.

Why the Earth Stays Warm

The sun gives off rays. Some of these are light rays that make it possible for you to see. Other rays from the sun produce heat when they hit the earth. The heated earth then reflects some of these rays. The reflected rays heat the atmosphere. Do these rays go back out into space? Some do, but most of them are "trapped" by the earth's atmosphere.

You can try this to help you understand the idea. Put your hand against the glass of a sunny window. Then put your hand on the wooden frame of the window. Which feels warmer? When the sun's rays reach the wood, the molecules in the wood become more active. The molecules now have more energy. Heat is produced and goes from the frame to your hand. But the rays can pass through glass. The glass molecules absorb few of the sun's rays. The glass is cool.

Now think of a greenhouse. Flowers can be grown there in the winter. Why is this so? The sun's rays go through the many panes of glass. They hit the soil around the plants. The soil becomes heated and gives off rays of its own. But these rays are different from the sun's rays. These rays *cannot* go back out through the glass. The glass acts like the earth's atmosphere and traps the heat rays. The rays are bounced back down, and the greenhouse is kept warm.

The earth is like a giant greenhouse. The sun's rays pass down through the atmosphere. When they reach the earth, the rays heat the earth. The heated earth then reflects some of the rays. But most of these rays do not pass back up through the atmosphere into space. They are trapped by the atmosphere and reflected back to earth.

The earth's atmosphere controls the amount of heat that the earth gets and loses. During the day the atmosphere screens out dangerous rays from the sun. At night and during the day it acts like a blanket and keeps much of the heat from escaping.

Without the atmosphere the earth would have temperatures similar to those

Learnings to Be Developed:

The sun's radiation heats the earth, which heats the atmosphere.

Since the earth's surface is heated unevenly, the air above it is heated unevenly.

Developing the Lesson: The following experiment will demonstrate the difference between absorption and reflection.

Set up two shallow containers on a sunny window sill. Place soil in one and water in the other. Insert a thermometer into each. Compare the temperature readings after 20 minutes.

ADDITIONAL ACTIVITIES:

To show the effect of absorbing surfaces on atmospheric temperature, or why the air is cooler over the water than over the land, proceed as follows:

Cover each container of the preceding experiment with a large beaker. Place an air thermometer on top of each beaker. Compare air-temperature readings after 15–20 minutes. Heat energy from absorbed rays in soil will warm the air trapped in the beaker.

(pp. 220–221)

LESSON: Why are some parts of the earth warmer than others?

Background: This lesson will illustrate another kind of difference in the temperatures of various parts of the earth. Here the difference results from the direction of the sun's rays rather than from the nature of the surface on which they fall.

Learnings to Be Developed: Since the earth's surface is heated unevenly, the air above it is heated unevenly.

Developing the Lesson: To illustrate the effect of vertical rays as compared to that of slanting rays of the sun, draw a horizontal line, representing a segment of the earth's surface, on the chalkboard. About a foot above this line, draw a short line parallel to it. From the parallel drop five vertical lines, 1 inch apart, to the "earth's surface," to represent four parallel rays striking the surface at right angles.

Now, draw a vertical line off to one side and from it draw another set of five lines, 1 inch apart, to the "earth's surface." These four "rays" will, of course, slant sharply and strike the surface at an angle.

of the moon. The sun's rays make the temperature on the bright side of the moon about as hot as boiling water. The side away from the sun has a temperature of about —238° F. Why do temperatures on the moon vary so greatly? Can you tell why temperatures on the earth do not vary as much?

Why Are Some Parts of the Earth Warmer Than Others?

You know that the equator has warmer temperatures than the poles. Why are some places on the earth warmer than others? You can find out by doing this activity.

Wet two thermometers. Shine a very bright light on the bulbs of the thermometers. Take readings of each thermometer every 30 seconds. Make a chart of your readings. Your record might look like the one shown at the bottom of this page.

Now put the thermometers in the sun at noontime. Stand one thermometer (B) straight up and lay the other (A) flat. Readings should be taken every 30 seconds. Make a chart of your readings. Your chart might look like the one on the next page.

Which thermometer, A or B, was heated more? Which rays heated the

	Thermometer A	Thermometer B
Reading 1	73°	73°
Reading 2	75°	74°
Reading 3	76°	75°
Reading 4	78°	76°
Reading 5	80°	77°
Reading 6	81°	78°
Reading 7	82°	79°
Reading 8	83°	80°

	Direct Rays (Flat Thermometer, A)	Slanting Rays (Standing Thermometer, B)
Reading 1	77°	76°
Reading 2	80°	78°
Reading 3	81°	79°
Reading 4	83°	80°
Reading 5	82°	78°
Reading 6	82°	78°
Reading 7	83°	79°
Reading 8	84°	80°
Reading 9	84°	80°

thermometers the most? Was it the direct rays or the slanted rays?

In a similar way, the sun's rays shine more directly on the equator than they do on the parts of the earth that are farther away from the equator. Because the rays are more direct and less slanted at the equator, the rays warm the earth more at the equator.

The air molecules at the equator have more energy. They move faster and take up more room. The air is less dense than the colder air above it. The molecules in the colder air are closer together, and the air is heavier. The force of gravity is greater on the cold air. The cold molecules move downward and force up the warmer air molecules.

The earth is unevenly heated. It also rotates as it revolves around the sun. The uneven heating of air and the rotation of the earth cause the air to move. Such movements of air are called winds.

Air Masses

In an area like the coast around the Gulf of Mexico, the earth becomes very warm. Large amounts of air are warmed by the earth. These large amounts of air are called **masses.** Colder air then

Call the children's attention to the fact that the vertical rays cover a smaller section of the surface than do the angled rays. In other words, vertical rays are more closely concentrated on a given area. Thus, when the sun's rays are at right angles to the earth's surface, the radiation is more concentrated and more heat is absorbed by the area.

ADDITIONAL ACTIVITIES:

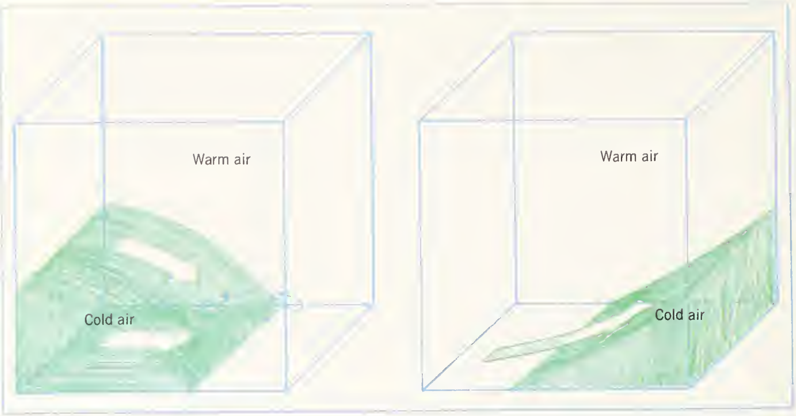
Show a model of the solar system. The children will be able to see that the sun's rays strike the earth at right angles at the equator. Have the class explore the implications of this.

Using the model of the solar system, explain that as the earth revolves about the sun, the area receiving nearly vertical rays is altered. The earth's axis (an imaginary line from the North Pole to the South Pole) is not truly vertical. Therefore, at one time of the year, an area north of the equator is more nearly perpendicular to the sun's rays, and at another time an area south of the equator is. This accounts for the difference in seasons between the Northern and Southern Hemispheres.

TEACHING SUGGESTIONS
(pp. 222–223)

Background: Fronts develop when air masses of different characteristics meet. When an advancing cold air mass meets a warm air mass, a *cold front* develops. The cold air, which is heavier, will hug the ground and force the warm air mass upward, as shown in the left-hand drawing. The sudden updraft of warm humid air causes the formation of *cumulonimbus* clouds, or thunderheads, and violent storms of short duration. These are followed by clearing and cooler, dry air.

A *warm front* develops when the warm air mass approaches a cold air mass. The warm air will creep over the cold air, as shown in the right-hand drawing, and the water vapor in its lower part will condense into the cold air beneath, forming a low overcast of *stratus* and *stratonimbus* clouds and producing prolonged drizzle and rain. A warm front approaches slowly and can be anticipated a day ahead by the appearance of high *cirrus* clouds, followed by *cirrostratus* and then stratus. *Nimbostratus* clouds appear the next day. When the sky clears, the air is warmer and more humid than before.



Explain what happens when a cold air mass meets a warm air mass.

moves in and pushes downward. The warmer air is forced upward. As the earth turns, this air goes to the southern United States and toward the east. This moving air, or wind, changes the weather in the places to which it moves.

In parts of Canada, the earth becomes very cold. The great masses of air become very cold and begin to move downward. Because of the turning of the earth, the cold air masses then move south and east. Such masses of moving air change the weather as they move.

When a warm air mass is above an area, the air there is mostly warm and moist. When a cold air mass is over a section of the country, the air there is mostly cool and dry. The weather changes when a warm mass of air meets a cold mass of air.

Sometimes when air masses meet, the cold air mass will push back the warm air mass. Sometimes the warm air mass pushes back the cold air mass. The first picture shows what happens when a cold air mass meets and pushes back a warm air mass. The other picture shows what happens when a warm air mass pushes back a cold air mass.

Highs and Lows

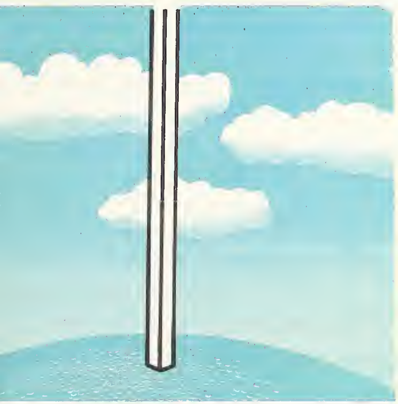
The air is made up of molecules of different kinds of gases. There are millions and millions of molecules in a

thimbleful of air. You cannot see a molecule even when you look through the strongest microscope. One molecule weighs almost nothing. But the billions and billions and billions of molecules piled up for hundreds of miles above the earth weigh a great deal.

A column of air molecules with a base that is 1 inch square, reaching from the ocean to the top of the atmosphere, weighs almost 15 pounds. Because of the weight of these molecules, the atmosphere pushes down on every square inch of the earth with a pressure of almost 15 pounds.

Think of many pillows, each of the same size and the same material.

A column of air 1 inch square at sea level will weigh almost 15 pounds. Will the air be more or less dense below sea level?



Imagine them piled on top of one another. What would happen to the bottom pillow? It has the same amount of stuffing in it as the others, but the weight of the pillows above it pushes the stuffing closer together. What would the middle pillow look like? What would the top pillow look like? Why?

Now think of the air near the earth. The pressure of the air is greatest near the earth. The molecules in the air are pushed closer together. The molecules are closer there because the pressure is greater. The air is dense near the earth. Compare the air at the top of a high mountain with the air at sea level. Where would the molecules be denser? Why?

The pressure of the air on the earth is called **atmospheric pressure.** It is 14.7 pounds per square inch at sea level.

But even in the same place, the atmospheric pressure does not always stay exactly the same. Sometimes it is higher, and sometimes it is lower.

When air pressure is higher in one place than in the others around it, weather scientists say that there is a "high" in that place. When air pressure is lower in one place than in the others around it, they say that there is a "low."

A high-pressure area, or high, starts where the air is cooled. The cooler,

When frontal systems do not move, they are called *stationary fronts,* and the prevailing bad weather persists until the front moves again and is replaced by the weather characteristic of the approaching air mass.

An *occluded front* may form when two cold air masses approach a warm air mass from opposite directions and cause the warm air to be lifted up.

Because moist air is lighter than dry air, the barometer always falls when a moisture-laden front approaches. A falling barometer usually means bad or wet weather; a bad-weather system is a *low.* Good weather is usually dry weather; the air is heavier, and the barometer rises. Good-weather systems are *highs.*

The patterns in which these fronts occur and the directions in which they move make up the climate of a region. In general, the climate of the United States is called *continental.* A continental climate is characterized by dry, hot summers and very cold winters. This is primarily because the moisture-laden winds blowing in from the Pacific Ocean release their moisture as they encounter the coastal ranges of the Pacific Northwest.

TEACHING SUGGESTIONS
(pp. 224–225)

Background: The answers to *Using What You Have Learned* are:

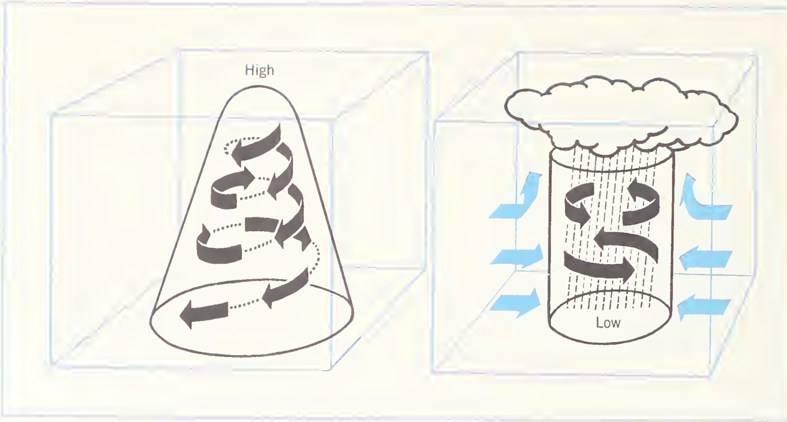
1. The mirror reflects the sun's rays; the black paper absorbs them. The paper will feel warmer.

2. The molecules are farther apart in warm air. There should be more dots in the drawing of the cold air. The dots representing the cold air should be closer together.

3. Suggestions for experiments:

a. Put carefully measured, equal amounts of water into two shallow pans. Set both pans on a table in a shady part of the classroom and place a fan between them, positioned in such a way that it will blow over one pan but not over the other. At the end of the school day measure the amount of water remaining in each pan.

b. Use alcohol in this experiment, because it evaporates faster than water and can show the effect more quickly and dramatically. After recording the temperature of the room thermometer, insert the bulb of the thermometer into alcohol and watch what happens. Note the rapid drop in the temperature indicated by the thermometer as the alcohol evap-



Use the two diagrams to explain how the air moves in a high and in a low.

heavier air starts to drop down, as shown in the diagram. It moves out from the center and forms a whirling wind. The wind whirls in the direction shown by the arrows.

A low-pressure area, or low, forms between highs. The center of the low is the place at which the atmospheric pressure is the lowest. Because the atmosphere around the low is denser, the air begins to form winds that move toward the center of the low. The diagram above shows how air moves in a low.

Highs generally bring fair weather and clear skies. Lows generally bring cloudy weather with rain or snow.

Using What You Have Learned

1. The sun's rays will not go through a mirror. They will not go through a piece of black paper either. Put a mirror and a piece of black paper in the sunlight. After they have been in the sunlight for about 15 minutes, feel them to see which is warmer. Why does one get warmer than the other?

2. Use dots to represent air molecules. Draw a diagram to show why a quart of warm air will not weigh as much as a quart of cold air. In which quart would there be more dots? In which quart would the dots be closer together?

3. Plan some experiments to test the following hypotheses:

a. Water evaporates faster in a strong wind than when there is no wind.

b. When water evaporates from an object, the object cools.

c. Warm water evaporates faster than cold water.

Keeping Records of the Atmosphere

A scientist who studies the weather is called a **meteorologist** (mee-tee-uh-ROL-uh-jist). Meteorologists try to get as much information about the atmosphere as they can to help them forecast the weather.

Forecasting tomorrow's weather starts with finding out what is happening in the atmosphere today. Records of the weather are kept in many different places by many people. In the United States, there are about four hundred weather stations where trained observers keep records of the atmosphere. Some stations are at the tops of high city buildings. Some are on mountaintops. Others are on the plains. There are also weather-observation ships on the ocean. Find out if you have a weather-observation station near you.

The meteorologists use instruments to get information about the atmosphere. You know about some of the instruments. What kind of information does the meteorologist get from each instrument?

Measuring and Recording Air Temperature

Meteorologists use thermometers that are somewhat like the one you have in your classroom. To measure the temperature of the air outdoors, they place their thermometers outside in places where the air moves freely. The thermometers are put in shaded places rather than in the sun. Can you tell why?

orates. Record the time and the new temperature. (This dramatic demonstration should be done by as many members of the class as possible, because the mercury column of the thermometer is visible only at close range.)

c. Construct two applicators by tying a bit of sponge to each of two rulers. Heat some water in a beaker and place some cold water in another beaker. Have two children simultaneously apply some hot and some cold water to two parts of the chalkboard. Time the rate of evaporation of each wet spot.

Follow-Up: Discuss some practical ways in which the facts just demonstrated can be used. Ask the children if the drying of wet clothes is affected by temperature.

- *Why do things dry faster out of doors on a breezy day?*
- *Why is an automatic clothes dryer heated?*
- *What happens on a cloudy day?*

Another example is the use of a water bag placed on the front of a car when driving over the desert. (Evaporation of the water cools the engine.)

TEACHING SUGGESTIONS
(pp. 226–227)

● **LESSON:** How and why is air temperature measured?

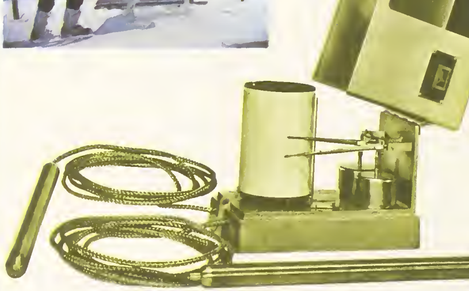
Learnings to Be Developed: Evidence regarding air temperature, among other things, is used in describing and predicting weather.

Developing the Lesson: Divide the class into groups and have each group construct a room thermometer as follows:

Fill a pyrex Erlenmeyer flask with water colored with red ink. Insert a glass tube through a one-holed rubber stopper and stopper the flask so that the tube extends into the water as well as several inches above the stopper. To the back of this upper portion of the tube attach a 3" x 5" white card with transparent tape. Make a mark on the card at the level of the colored water in the tube. Set flask aside (away from window or radiator) for a day, so water in flask can reach room temperature.

Next day, check the room thermometer for the day's reading, note water level in tube, mark level on the card, and note beside it the day's temperature.

Make similar markings daily to develop a scale of temperatures on the card.



In shelters like the one in the picture above, there are several instruments. There is generally a thermometer. There is also another instrument that measures heat, called a **thermograph** (THER-muh-graf). *Thermo* means "heat," and *graph* means "writing."

One part of a thermograph is a metal tube that contains a liquid. As the temperature of the air changes, the curve of the tube changes. Can you tell why this happens? Another part of the thermograph is a pen that is fastened to one end of a metal arm. The other end of the arm is attached to the metal tube. Look at the picture. As the curve of the tube changes, the pen moves up or down on a sheet of paper that is wrapped around a drum. This drum makes one complete turn in a week. The paper is marked off into days and hours. A new sheet of paper is put on the drum every week. From the thermograph sheets, a meteorologist can tell what the temperatures were all throughout the week.

There are two other kinds of thermometers in the shelter. One is a **maximum thermometer.** This shows the highest temperature for each day. The other thermometer in the shelter is the **minimum thermometer.** This tells the lowest temperature for the day. Ordinary thermometers only tell you what the air temperature is when you look at them.

You can keep a good record of air temperature with your thermometer. The thermometer should be protected from the sun and kept off the ground. Can you tell why? Should it be hung on the north or south side of a building? Six feet from the ground is the best height. It is better to put the thermometer over a grassy place than over a stony place. Why do you think this is so? Take thermometer readings at the same times each day. Why is this important?

Knowing the air temperatures in different places and how the temperatures change helps a meteorologist keep a good record of the weather.

Measuring and Recording Atmospheric Pressure

Knowing the atmospheric pressure at different places aids the meteorologist in finding the highs and lows. **Barometers** (buh-ROM-uh-terz) measure the atmospheric pressure. The word *barometer* means "weight measure." Mercury barometers are the most exact kinds of barometers.

Listen to a weather report given on the radio or television. What is the barometric pressure?

Another kind of barometer is the **aneroid barometer** (AN-er-oyd). The important part of this instrument is a

Above you see a mercury barometer; below is an aneroid barometer. Find out how each works.

After the thermometer has been constructed and set aside until the following day, a discussion can be held on the general subject of calibrating the thermometer just constructed.

- *What does "calibration" mean?* (Positions of scale markings for various temperatures must be determined or checked for correctness before thermometer can be of any use.)

Recall the work covered in the previous unit on freezing points and boiling points, and ask for practical suggestions for full calibration of the flask thermometer. (For example, place the flask in a large container and surround it with a mixture of ice and water. Let stand for several hours and note the level of water in the tube. It will represent 32° F., the freezing point of water. If the flask is kept in a container of boiling water, the level will show 212° F., the boiling point of water. The distance between the two points can then be divided into 180 equal units, which you may call *degrees*.)

You might prefer to introduce the metric system at this time, by labeling the freezing point of water 0° and the boiling point 100°. Point out that the Farenheit and Centrigrade scales are equally arbitrary.

TEACHING SUGGESTIONS
(pp. 228–229)

Background: Clouds are formed when water vapor is cooled and tiny water droplets condense on dust particles in the air. In the upper layers of the troposphere, water condenses at a temperature below freezing. Ice crystals form. This results in a wispy, feather-like, thin cloud called a *cirrus* cloud.

When humidity is very high or the cooling of air is very rapid, rain clouds develop. In such a *nimbus* cloud, the water droplets grow in size rapidly and become too heavy to remain suspended in the air. As they are pulled to the ground by gravity, they become rain. *Cumulonimbus* clouds, or thunderheads, develop on hot summer days over land. Hot, humid air rises very rapidly, and colder air rushes down. The cloud that forms is very high (its top may be 6 miles up). The dark bottom of the cloud may be only 1 mile above the ground. Airplane pilots avoid these clouds because of the rapid movement of air within them. Sudden downdrafts or updrafts can toss large airplanes as if they were chips on water and cause the pilot to lose control.

How Does a Mercury Barometer Work?

What You Will Need

glass tube 36 inches long, closed at one end

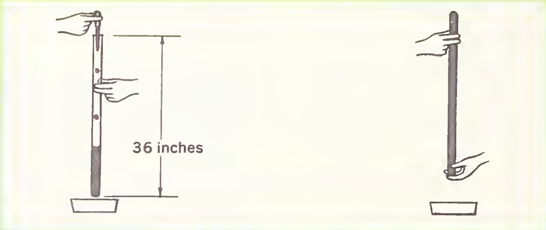
mercury in small pan or dish

yardstick

medicine dropper

How You Can Find Out

1. With the medicine dropper fill the tube with mercury. Hold the tube over the pan or dish of mercury in case some should spill. From time to time, shake the tube up and down to get the mercury past any air pockets. Fill the tube completely.
2. After the tube is filled, hold one finger over the open end and carefully turn the tube upside down in the pan of mercury. Keep your finger on the end until the end of the tube is under the mercury.
3. Remove your finger. Some mercury will run out of the tube.



Questions to Think About

1. Why does some of the mercury run out of the tube?
2. Use the yardstick to measure the vertical distance from the top of the mercury in the pan to the top of the mercury in the tube. Why is atmospheric pressure measured in inches of mercury?
3. As the atmospheric pressure increases, what will happen to the column of mercury in the tube?
4. As the atmospheric pressure decreases, what will happen?

round metal box. Most of the air has been removed from the box. The box is easily pushed in or out. A spring inside the box keeps the sides from caving in. As outside air pressure increases or decreases, the sides bend in or out. As the sides move in and out, they move a needle back and forth. The needle points to numbers on a paper. These numbers tell the atmospheric pressure.

Do you see how an aneroid barometer could be used to obtain a weekly record of atmospheric pressure?

Information from Clouds

Clouds provide much information about weather changes. Do you know how a cloud forms? Water evaporates into the atmosphere and becomes the gas called water vapor. Air is constantly moving, and some of that movement is upward. As the air moves up away from the earth it becomes cooler. Some of the water vapor in the air changes back into a liquid. It is then called a cloud.

Sometimes clouds look very thin. At other times they appear large and puffy. Sometimes the clouds look white. Sometimes they look gray or black. Meteorologists observe the clouds to obtain weather information.

Meteorologists have a system of classification for clouds. They have sorted them into ten main groups. You can learn to know the three groups that are seen most often. You can learn to know what these clouds mean.

The light, puffy clouds that you often see in the sky are called **cumulus clouds** (KYOOM-yuh-luss). *Cumulus* means "pile" or "heap." You often see such clouds in the summer sky.

Cumulus clouds form when warm air containing water vapor rises into the sky. At the place where the water vapor begins to condense, the bottom of a cumulus cloud begins to form. You might think of each puffy cloud as something that is sitting on top of a rising column of warm air. The bottoms of these clouds are usually not more than a mile above the ground. Some cumulus clouds are not very thick, but others may be six or seven miles thick.

Sometimes on a summer day there will be no clouds in the sky in the early morning. But then the sun starts to heat the earth. Later little puffs of cumulus clouds appear. Why?

In the afternoon, as more and more warm air rises, the cumulus clouds get larger and larger. But what starts to happen at sunset? Does as much warm air keep rising? Does as much water evaporate? Do the clouds get larger or smaller? *

* *Air cools at sunset. Water evaporates more slowly from land surfaces than from water surfaces. The clouds get smaller.*

The answers to the *Questions to Think About* on page 228 are:

1. Normal barometric air pressure is equal to a column of mercury 29.92 inches high. The atmospheric pressure pressing downward on the open pan exerts a pressure against the mercury that is just equal to a column of mercury that is 29.92 inches high. Therefore, some of the mercury in the 36-inch column will run out of the tube.

2. The height of the column of mercury will be approximately 29.92 inches, as explained in answer #1. Atmospheric pressure is measured in inches of mercury for historical reasons and, in fact, is little used today.

3. As the atmospheric pressure increases, it will exert a greater pressure on the mercury in the open pan, forcing the column of mercury higher into the tubing. Then, of course, the barometer rises.

4. As the atmospheric pressure decreases, the reverse of the above occurs. The atmospheric pressure on the mercury in the open pan decreases, and the weight of the mercury in the column acting against the atmospheric pressure causes the column to drop. The barometer drops.

TEACHING SUGGESTIONS
(pp. 230–231)

LESSON: How does a cloud form?

Background: As previously explained, heat from the sun causes evaporation of water from the surface of the earth, and condensation of water vapor upon contact with cooler air produces clouds. In this lesson, the combined effects of heat and condensation are demonstrated. Also, the necessity for dust particles (which serve as nuclei for condensation of water vapor) will be emphasized.

Learnings to Be Developed: Heat and water produce changes in the atmosphere that result in changes in weather.

Developing the Lesson: To make a cloud, fill a milk bottle with hot water, and then pour out all but 1 or 2 inches of the water. "Seed" the air in the bottle by holding a lighted match inside the mouth of the bottle for a few seconds. Now place an ice cube on the mouth of the bottle (the cube must be large enough not to fall into the bottle). A cloud will begin to form near the ice cube as the water vapor in the bottle cools and condenses on the soot particles introduced by the incomplete combustion of the match.

Cumulus clouds are light and puffy.

CLOUD TYPES

Keep a record for two or three weeks of the kinds of clouds you see each day and the weather for that day. Does knowing what kinds of clouds you are seeing help you to predict the weather?

Cirrus clouds are thin and curly.

Stratus clouds look like gray sheets.

Sometimes the air rises very quickly on a summer day. The tops of the cumulus clouds reach higher and higher. The tops of the clouds may be in very cold air. The air whirls fast that high—sometimes as fast as 100 miles an hour. In other parts of the clouds, cold air is rushing down. Thunderclouds form. Wind, driving rain, and hail can come from these clouds. Sometimes they produce **tornadoes.**

Cirrus clouds (SIR-uss) are high in the sky. Their bottoms are sometimes ten miles from the ground. They are up where winds are blowing fast. Cirrus clouds may move as fast as 120 to 200 miles an hour. They are very thin, curly clouds, made of bits of ice.

Sometimes cirrus clouds appear after several fair days. Quite often they are formed ahead of either a cold or a warm air mass. They are a sign that bad weather is coming in a day or two.

When you see a gray sheet of clouds covering the sky, you are seeing **stratus clouds** (STRAY-tuss). *Stratus* means "layer." Usually, stratus clouds mean that it will soon rain. The rain which comes from such clouds is usually steady.

Measuring Wind Speed and Direction

People often want to know the speed and direction of the wind. Can you see why an airplane pilot would want this information? Would such information be helpful to a man working on a high building or going out in a sailboat?

The speed and direction of the wind are important to meteorologists, too. Meteorologists can tell much about the coming weather by studying the wind.

Winds are named for the direction from which they come. What would a wind coming from the southwest be called? What would a wind blowing from the east be called?

A **wind vane** can be used to find wind direction. A wind vane should be kept away from any buildings and trees. Why do you think this should be done?

One type of wind vane is attached to a pen. The direction of the wind is recorded every minute. The pen makes dots on a piece of paper that is attached to a revolving drum. By looking at these dots, the meteorologist can tell when the wind direction changes.

An **anemometer** (an-uh-MOM-uh-ter) is used to find out how fast the wind is moving. There are various types of anemometers. One kind has cups at the ends of arms. When the wind hits these cups, the cups cause the arms to whirl around and around. The stronger the wind, the faster they move. The speed at which they whirl is shown on a dial.

Follow-Up: To dramatize the importance of the dust particles, boil water vigorously in a tea kettle or other pot with a spout. Point out to the class the space between the end of the spout and the beginning of the visible cloud of steam. The space is filled with invisible gas—water vapor. The steam is composed of water droplets that have condensed on particles of dust in the air.

Raindrops need not form only on dust, of course, although most raindrops do form on dust particles swept into the air by the wind. Raindrops will also form around particles of salt swept up from the surface of the ocean by the wind and carried high into the atmosphere. Raindrops will also form on meteoric dust, the remains of meteors that have been destroyed as they entered the earth's atmosphere. In fact, scientists believe that they have now discovered a relationship between annual meteoric showers that occur and the general pattern of rainfall over the earth. Raindrops will also form around particles of smoke, soot, and ash that fill the air from man's inventions, as well as from natural holocausts such as volcanic eruptions and forest fires. In fact, almost any kind of particle is sufficient for a drop to form.

TEACHING SUGGESTIONS
(pp. 232–233)

● **LESSON:** How and why do we measure humidity?

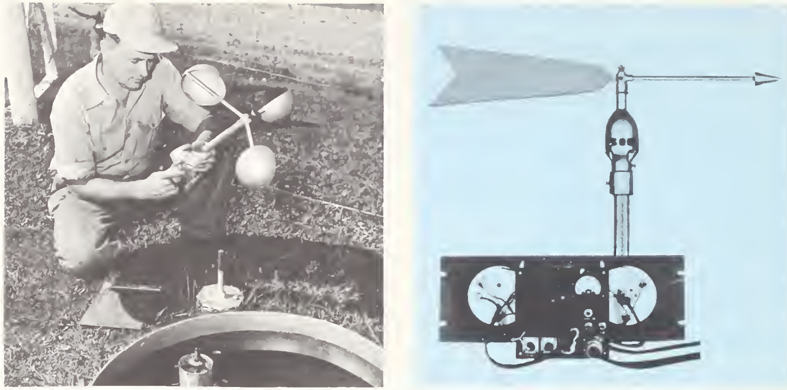
Learnings to Be Developed: Evidence regarding humidity is used to describe and predict weather.

Developing the Lesson: Ask pupils if they have noticed a difference in the texture of their hair on damp days. Elicit or suggest that human hair might be used to detect differences in the humidity of the air.

Select a long human hair. Remove all oils by soaking it in carbon tetrachloride for a few minutes, and allow it to dry. To one end of a wood block or flat stick attach a cardboard pointer by means of a pin or thumbtack swivel. Glue one end of the hair to the pointer and the other to the opposite end of the block or stick of wood. As the hair expands (when the surrounding air is damp) or contracts (when the air is dry), it moves the pointer through an arc that can be marked for high and low humidity.

ADDITIONAL ACTIVITIES:

A cobalt chloride hygrometer may be constructed as follows. Prepare a solution of $CoCl_2$ and soak several sheets of white paper in it



A weatherman reads the wind speed from an anemometer. Can you tell how the anemometer works? How does the wind vane on the right work?

The dial shows the speed in miles per hour. The anemometer, like a wind vane, is usually connected to a recording drum so that the wind speed can be read inside the weather station.

Measuring Relative Humidity

On some days you feel very comfortable. On other days you feel hot and sticky. How you feel depends partly on the amount of water vapor that is in the air.

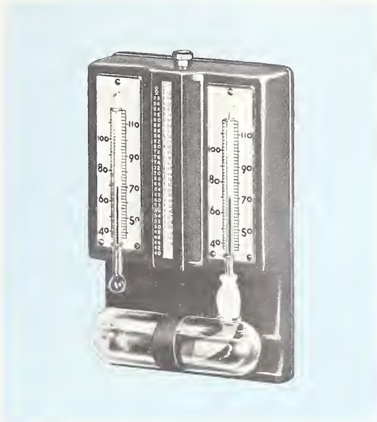
Relative humidity (yoo-MID-uh-tee) is the amount of water vapor in the air compared with the greatest amount that *could* be in the air at a specific temperature. When the air is holding all the water vapor it can, we say the relative humidity is 100 per cent.

The humidity has a great deal to do with your comfort. It is also important in many other ways. For example, if you were planning to hang out laundry, would you want the humidity to be high or low? Or if you were a fire ranger, would you be very concerned about humidity? Fires can start easily on hot days when there is little water vapor in the air. Dead leaves and plants are drier on such days and catch fire more easily.

Warm air can hold more water vapor than cool air. What happens when warm air containing much water vapor becomes cooler?

The instruments used by meteorologists to measure relative humidity are **hygrometers** (hy-GROM-uh-terz). The type of hygrometer most commonly used has two thermometers, one with a wet bulb and the other with a dry bulb.

Here is an example of how the hygrometer works. Suppose the dry-bulb reading was 70° F. and the wet-bulb reading was 65° F. The difference is 5° F. If you move down the 70°-74° column to the 5° line, you come to 78. The relative humidity is about 78 per cent. This means that the air is holding about 78 per cent of the water vapor it could hold at that temperature.



A hygrometer measures relative humidity. Notice that there are two thermometers—one wet-bulb and one dry-bulb thermometer.

Measuring Precipitation

The falling of rain or snow is called **precipitation** (prih-sip-uh-TAY-shun). Meteorologists keep track of how much rain or snow falls every day.

The farmer needs to know about rainfall, especially if he irrigates his crops. He needs to know how much water there will be.

In areas such as the Mississippi Valley, precipitation records are watched very carefully. Heavy snowfalls during the winter may mean floods during the spring. Cities and towns in many other places also keep precipitation records. The water supplies of these cities and

RELATIVE HUMIDITY CHART

Difference between temperatures of dry-bulb and wet-bulb thermometers	Temperature of dry-bulb thermometer		
	65°-69°	70°-74°	75°-79°
2°	90	91	91
3°	85	86	87
4°	80	82	83
5°	76	78	79
6°	71	73	75
7°	67	69	71
8°	62	65	67
9°	58	61	63

for 5 minutes. Remove and dry the papers. Cut them into pieces and pin the pieces at various places inside and outside the classroom. They will lose their blue color as the humidity of the air increases and regain the color as the air dries. Compare the "forecasts" thus obtained with the actual weather and judge their reliability. (Remember that just breathing on the cobalt paper will affect it.)

A psychrometer to show relative humidity can be constructed easily. Mount two identical thermometers on a block of wood. Wrap around the bulb of one thermometer one end of a strip of toweling or a white shoelace. Insert other end of towel or lace into beaker of water to establish a continuous wet wick. Use the table at the bottom of page 233 to compute the relative humidity from wet-bulb and dry-bulb readings.

Why must the shoelace be white rather than brown or black? (White reflects and dark absorbs heat rays. The wet-bulb reading would not be reliable if it were affected by a temperature other than that of evaporation.)

TEACHING SUGGESTIONS
(pp. 234–235)

Background: Condensation of water vapor takes many forms, the most common of which is *rain*.

Snow forms when water vapor crystallizes directly into flakes without going through a liquid stage.

Hail forms in thunderclouds. As rain falls through the cloud, it freezes. Strong updrafts carry the frozen drops up again, and more water vapor condenses on them. As they fall once more, this water also freezes. If the frozen drops are carried up again, and the process is repeated many times, hailstones of considerable size can be formed.

Where do you see a funnel on this rain gauge? If 25 inches of water collect in the narrow measuring tube, how many inches of rain fell?

towns may depend on how much rain and snow falls.

The instrument for measuring rain and snow is probably the oldest weather instrument in the world. It is called a **rain gauge** (gayj). As early as 1442, the Korean people used a simple kind of rain gauge to measure precipitation. This simple rain gauge is placed away from buildings and trees. Can you tell why? The rain gauge can measure up to an inch of rainfall.

It is important to measure precipitation to the nearest one hundredth of an inch. An extra one hundredth of an inch of precipitation could mean, for example, that the seeds a farmer has planted will grow. But how do meteorologists measure such a small amount of precipitation?

Meteorologists catch the rain in a large funnel. The water passes through the bottom of the funnel into a narrow measuring tube. The width of this tube is one tenth of the width of the top of the funnel.

The tube is constructed so that if 10 inches collect in the narrow tube, it means that there has been 1 inch of actual rainfall. Why is this helpful in measuring a light rainfall?

Snow is harder to measure than rain. Wind piles it up in drifts. This causes snow to differ in depth from one place to

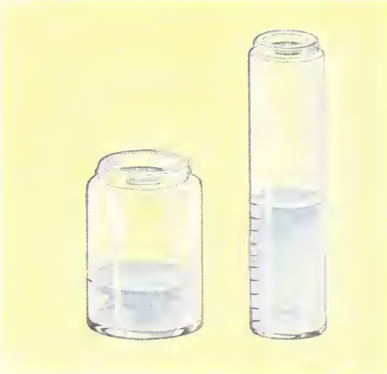
another. Sometimes snow is gathered in a rain gauge and then melted. Then it is measured. About 10 inches of snow equals the water in 1 inch of rain.

Usually the depth of snow on a flat surface, such as a roof, is measured with a ruler or yardstick. Readings are taken in three places where the snow has not drifted. Then these figures are averaged. This average figure is considered the amount of snowfall. Let us say the readings are 3½, 3¼, and 3¼ inches. To find the average you add all three readings and divide by 3. What is your answer? Do you get 3⅓ inches as the amount of snowfall?

Make a rain gauge. Use a jar with straight sides and a flat bottom. Why should you use such a jar? Where should you place this jar? How can you measure the rainfall?

This gauge will give you accurate precipitation readings only when there is a heavy rainfall. You can build a more useful gauge by copying the weather bureau's gauge.

Pour 1 inch of water into a wide jar. Now pour this water into a narrow jar. This was 1 inch of water in the wider jar, but now, in a longer, narrower jar, it is more than 1 inch. Mark the jar at the exact top of the water in the jar. Now divide the space between the bottom of the jar and your mark into ten equal parts. After you do that, mark off the spaces. What does each mark measure?



By leaving the larger jar outside during rain, you can tell the amount of rainfall. How are you able to do this?

The next time it rains, leave the large jar outside. Then pour all the rain from this jar into your rain gauge. If the water reaches the halfway mark on your scale, there has been one-half inch of precipitation.

Must you always use the same large jar that you used to make your gauge? Why?

Measuring Visibility

How far can you see on a clear day? How far can you see on a cloudy day?

Sleet is frozen rain that is formed as rain falls through air at temperatures below freezing.

Dew occurs when water vapor condenses on a cold surface; if the temperature of the surface is below 32° F., *frost* is formed.

Fog is a low cloud. It forms when water vapor condenses on dust particles close to the ground or on salt particles near the surface of a body of cold salt water. Fog occurs when warm, moist air passes over a cold body of land or water. It also frequently forms in valleys during the early hours of the morning; such fog is referred to as *mist*.

TEACHING SUGGESTIONS
(pp. 236–237)

LESSON: How is weather described and predicted?

Learnings to Be Developed: Evidence regarding air temperature, relative humidity, wind speed and direction, and atmospheric pressure can help describe and predict weather.

Developing the Lesson: Have the class set up a weather station. The weather instruments made by the children can be used together with any instruments available in the school. Committees can be formed and responsibility delegated for various tasks.

Accurate charts should be kept showing daily readings of temperature, barometric pressure, relative humidity, wind direction and velocity, cloud formation, and cloud height. These data should be compared, for accuracy, with the daily news reports.

The children should follow the daily weather reports and watch for approaching weather fronts. Effects of the fronts, both before and after, should be noted in relation to temperature, pressure, humidity, wind direction, etc. The significance of fronts for prediction should be discussed (review text page 222 and use of the material on pages 238–241).

Visibility (viz-uh-BIL-uh-tee) is the distance that you can see along the surface of the ground. Visibility is not always measured with an instrument. The meteorologist at a weather station knows the exact distance to certain objects outside. A tall tree may be one-half mile away. A tall building may be three fourths of a mile away. If the meteorologist can see as far as the tree but no farther, he says the visibility is one-half mile. The visibility is the farthest that he can see at that time.

Visibility on runways at airports or jetports is measured with a **transmissometer** (tranz-miss-SOM-uh-ter). Find out how it works. Perhaps someone at your local weather bureau can help you.

Measuring Weather High in the Atmosphere

The instruments that have been described so far are those which are used for observing the atmosphere near the ground. But meteorologists also study the atmosphere higher up, because it too plays a part in making weather on the surface of the earth.

Meteorologists have ways to measure the height of clouds and the speed and direction of winds high above the earth. They also have ways to measure the temperature, relative humidity, and atmospheric pressure of the air at high altitudes. The picture story that begins on page 242 shows and discusses some of the instruments used by meteorologists.

Radar

Radar (RAY-dahr) is used to locate storms and follow their movements closely. Radio waves are sent out from the radar instrument. When the radio waves hit objects such as clouds, the waves are **reflected,** or bounced back. A radar receiver picks up the reflected waves. These reflected waves make a picture on a screen of the objects that have reflected the waves. Some cloud patterns mean that severe storms are coming.

Balloons

Weather stations send balloons filled with a lighter-than-air gas into the atmosphere. As these balloons rise, they are watched carefully with special telescopes. The way they rise or are blown about can tell a meteorologist much about the winds in different layers of the atmosphere. By observing the balloons, the meteorologist can figure out the speeds and directions of high winds.

Using What You Have Learned

1. Hang one thermometer in the sun. Place a second thermometer near it, but place it in the shade. How do the temperatures recorded by the two thermometers differ? Which thermometer gives a more exact reading of the air temperature?

2. Measure the exact distances to certain objects from your classroom window. Then keep a visibility record for one week. At the same time each day, note how far you can see.

3. Keep a precipitation record. You will need a rain gauge. Here is a sample record. Reread the pages describing the rain gauge to refresh your memory.

NOVEMBER

Date	Precipitation
1	.2
2	0
3	0
4	1.4
5	.3
6	0

Weather Maps and Forecasting

One of the jobs of the United States Weather Bureau is to forecast the weather. To make forecasts it works with the Army, Navy, and Air Force and airlines that fly planes all over the United States. It employs a large number of meteorologists to carry on its work. Thousands of volunteers help to keep records of the weather in the places where they live. The weather can be forecast only with the cooperation of many persons. Why is such cooperation necessary?

Making Weather Maps

Some of the weather-observation stations shown on the map on page 238 report every six hours to weather-forecasting centers in the United States. Others report every hour. These reports include information about atmospheric pressure, air temperature, wind speed, wind direction, clouds, visibility, and precipitation. All the stations send out their reports at the same time. The meteorologists in each forecasting center learn from these reports what

If not available in local newspapers, daily weather maps can be obtained by writing the U.S. Weather Bureau, Department of Commerce, Washington, D.C., 20025.

○ **ADDITIONAL ACTIVITIES:**

The importance in history of certain weather conditions (for example, Eisenhower's D-Day decision for the invasion of Europe during World War II or Napoleon's disastrous retreat from Russia through snow and bitter cold in 1812) might be discussed in class.

The validity of certain weather superstitions might be discussed in class. For example, "If the groundhog sees his shadow on February 2, we will have six more weeks of winter," or, "If it rains on St. Swithin's day (July 15), we will have 40 days of rain." Weather records as well as personal observations can be applied to the discussions.

Ask for volunteers to search out and report on simple methods for the construction of a wind vane, a barometer, and an anemometer. (Remind the children that they must be able to calibrate their instruments. Otherwise, the data collected will be of doubtful value.)

TEACHING SUGGESTIONS
(pp. 238–239)

Background: The atmosphere around the earth is made up of a number of air masses that acquire various characteristics as they move over land or water. The air masses affecting the coterminous United States are:

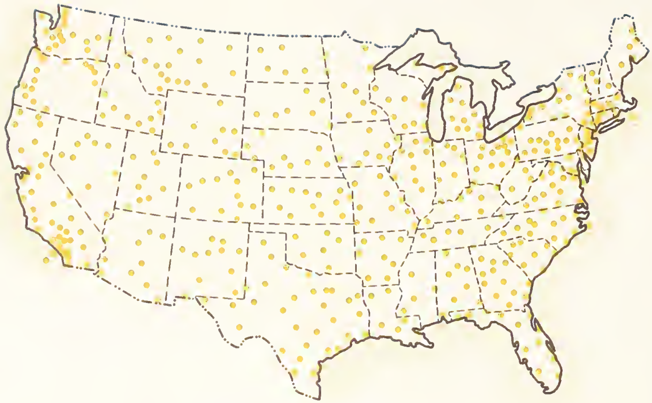
Polar Continental. The name indicates its origin and direction. Its characteristics can be inferred. The only continental mass north of the United States is Canada. Air moving over cold land is probably cold and dry. Thus polar continental air is cold, dry air that comes from Canada.

Polar Maritime. This is cold, moist air that comes from either the North Atlantic Ocean or the North Pacific Ocean.

Polar Pacific. This is cold, dry air flowing in a southeasterly direction from the Arctic across Canada to the Plains states and the Midwest.

Tropical Atlantic. This is warm, moist air flowing in a northwesterly direction from the South Atlantic.

Tropical Gulf. This is warm, moist air flowing in a northeasterly direction from the Caribbean.



SOME WEATHER-OBSERVATION STATIONS IN THE UNITED STATES

the atmosphere is like in many different places. They record all of this information on large maps of the United States.

First the forecasting expert draws lines on the map to show those places where the atmospheric pressure is the same. These lines are called **isobars** (EYE-suh-bahrz). *Iso* means "equal." *Bar,* as in *barometer,* means "weight." In all places along an isobar, the atmosphere has the same weight, or pressure.

You can see the isobars in color on the map on the next page. Each isobar has two numbers on it. These numbers tell the atmospheric pressure. The smaller number tells what the pressure is in inches of mercury. The larger number gives the pressure in **millibars** (MIL-uh-bahrz). A millibar is another unit for measuring atmospheric pressure.

After the isobars are drawn on a map like the one on the next page, the forecaster can tell the location of the highs and the lows. You can see a high over the Great Lakes extending down through Cincinnati. Look at the isobar marked 30.12 in small numbers. What does this mean? A low was near Boston. Look at the isobar near the center of this low. It is marked 29.53 in the small numbers. What does this mean? Find other highs and lows.

Finding the Air Masses

When the reports come in, the temperature at each station is written on the map. Look at the map shown on page 240. The number in color tells the temperature at each station. Find Moosonee and Sault Ste. Marie. (Moosonee is in northern Ontario, Canada; Sault Ste. Marie is in Ontario on the border between Canada and the United States.) It is 44° F. at Moosonee. What is the temperature at Sault Ste. Marie? What is the temperature at Bismarck, North Dakota? What is the temperature at Minneapolis, Minnesota? The forecaster uses the information about air temperature to locate cold air masses.

The edge of a cold air mass is shown by a line with points on it. The edge of a warm air mass is shown by a line with bumps on it. The points or bumps show the direction in which an air mass is moving. On the map on page 240, find the line that goes from Calgary, Alberta, through Bismarck and then up to Moosonee. The points on the line show that the cold air mass is moving south, further into the United States. How does the forecaster know this? Can you find a cold air mass that is moving from Salt Lake City, Utah, toward Denver, Colorado?

Tropical Pacific. This is warm, moist air flowing in a northeasterly direction from the South Pacific.

Tropical Continental. This is hot, dry air flowing in a northeasterly direction from Central America and Mexico.

ADDITIONAL ACTIVITIES:

Have the children watch a television weather report and note the arrows indicating the movement of air masses. How did the weather reporter describe them? What did he say about how they were affecting, or would affect, the local weather?

Discuss: Which air masses usually affect the area where you live? Are they the same in summer as in winter? What kind of weather do you have as a result?

If you live in an area where the barometric pressure changes much (particularly when there are thunderstorms), ask the children if they have ever noticed the change in air pressure. For example, did they ever have a funny feeling in their ears? Did they ever have a similar feeling in an airplane?

TEACHING SUGGESTIONS
(pp. 240–241)

● **LESSON:** What is a weather map?

Background: Review the material on highs and lows and cold and warm fronts on page 222 for inclusion in the discussion of weather maps.

Learnings to Be Developed: Weather maps are used in reporting weather over a large area.

Developing the Lesson: Discuss the various weather facts that are shown on a weather map, using the three maps on pages 239, 240, and 241. Point out the decimal number (.03) below the temperature for Salt Lake City on the map on page 240; this is the amount (in inches) of rainfall during the 6 hours preceding the time of the map. Another such number appears near Winnipeg on the map on page 241. That map also shows, by means of shading, the areas where rain fell during the preceding 6 hours.

Distribute outline maps of the United States on which are indicated main rivers, mountain ranges, and several major cities. Have the children make their own weather maps using data from Weather Bureau reports or newspapers.

Cold and Warm Fronts

The place where the edges of a warm air mass and a cold air mass meet is called a *front*. A **cold front** is the place where a cold air mass moves forward along the ground and replaces a warm air mass. A **warm front** occurs when a warm air mass moves forward to take the place of a cold air mass. On weather maps the bumps indicate the direction of movement of a warm front. The points of the triangles indicate the direction of movement of a cold front. The map here shows a cold front which goes from Calgary to Bismarck and then north to Moosonee. Can you find a warm front on the map?

The front south of Galveston and New Orleans has bumps on one side and points on the other. At the time the map was made, neither the cold nor the warm air mass was moving. This is called a **stationary front.**

Winds, Clouds, and Precipitation

If a weather map is to be useful to the forecaster, there must be a great deal of information on it. It must tell more than just the locations of highs, lows, and air masses. Winds must also be shown. The map must tell where it is cloudy and where it is foggy. The location of rainy and snowy areas must be given. In order to get all this informa-

tion on a weather map, the meteorologist uses signs, or a code. You have already seen one kind of code. You have seen how lines, or isobars, are used to show pressure and how another kind of line is used to show fronts.

The signs on a weather map are explained in a key. By using the key on the map below, see if you can tell what the symbol on the map near Oklahoma City, Oklahoma, means. What kind of weather is there in Oklahoma City? In what direction are the winds blowing? How fast?

Below is a weather map as it would look in a newspaper. Can you answer these questions by studying the map?

1. What is the atmospheric pressure in Galveston, Texas; Seattle, Washington; and New York City?

2. What are the temperature readings in Oklahoma City, Oklahoma; Atlanta, Georgia; and Miami, Florida?

3. What is the sky like in Sault Ste. Marie, Ontario; Fort Worth, Texas; and Tampa, Florida?

4. Where is it raining?

5. How much rain has fallen in Richmond, Virginia?

6. Where is the wind stronger, in San Francisco, California; or Chicago, Illinois?

7. What is the force of the wind at Sault Ste. Marie?

If complete local data are available, have the children use all the appropriate symbols on their maps to describe the local weather.

Background: The answers to the questions on page 241 are:

1. Galveston, 30.00; Seattle, between 29.41 and 29.53; New York City, between 29.77 and 29.87.

2. Oklahoma City, 66°; Atlanta, 62°; Miami, 73°.

3. Sault Ste. Marie, clear; Fort Worth, clear; Tampa, clear.

4. It is raining in California, the coast of Oregon, and in the Plains states from North Dakota to Oklahoma. Rain is also reported in Los Angeles, Albuquerque, Winnipeg, and Richmond.

5. Not shown on map.

6. The same, at 9–14 miles per hour.

7. There is no wind reported at Sault Ste. Marie.

ADDITIONAL ACTIVITIES:

Either individually or in groups, the children can select particular areas and make weather predictions, giving reasons for each prediction. A record can be kept over a period of time and some notice taken of the individual or group with the best prediction record.

Have pupils draw their own weather maps on desk outline maps of the United States. Let pupils make daily changes on your chalkboard outline map.

TEACHING SUGGESTIONS
(p. 242)

LESSON: Why are weather reporting and predicting important?

Learnings to Be Developed: Weather affects everyone's life.

Developing the Lesson: Discuss the effects of weather the children may have experienced, from inconvenience to economic effects. In an agricultural community, the importance of rain to crops should be mentioned; in a city, the effects of weather on such outdoor activities as building construction may be more obvious.

- *Name other activities that are affected by weather.* (Sports, vacations, transportation, clothing sales, etc.)
- *Consider the damage done by some types of storms. Why do people living in Florida need to know about approaching hurricanes?* (To protect themselves and their property.)
- *What are some of the effects of droughts?* (Crops are reduced or destroyed. Water shortages may develop.)
- *Is accurate weather forecasting possible from weather reports gathered in the United States alone?* (No; reports are needed from all over the world.)

Making a Forecast

You can tell from a weather map what the weather is like in different parts of the United States. But a map alone does not tell what the weather is going to be like tonight or tomorrow morning. A forecaster needs to know other things to make such predictions. He needs to know how the air masses, and the highs and lows that go along with them, move across the country. He needs to know how fast they move and the general direction in which they move. The forecaster needs to know what kinds of weather go along with highs and lows.

How might a weather forecaster in Cincinnati, Ohio, use the map on page 239? Now it is partly cloudy in Cincinnati. But in all places near the center of the high, skies are clear. How can you tell this from the map? When the high that now has its center at Kansas City reaches Cincinnati, how will Cincinnati's weather change? The weather forecaster can be fairly certain that the skies will be clear in Cincinnati when the high gets there. Highs generally bring clear weather. The forecaster has been charting the movement of this high on his maps every six hours. From his records, he can expect the high to be in Cincinnati in about twelve hours. Now he is ready to make his forecast: "Clear and slightly warmer tomorrow morning."

The expert forecaster knows how high mountains will affect the weather. He has learned about this from his study of meteorology. His records show what it was like in the past when various weather conditions came to his area. Using his past records and his present information, the meteorolgist can forecast correctly nine times out of ten.

ABOUT "A VISIT TO THE WEATHER BUREAU"

The United States Weather Bureau, an agency of the United States Department of Commerce, provides a national weather-reporting service. The bureau also issues forecasts and warnings of weather conditions that may affect the nation's safety and economy. In the next eight pages, you will tour, through pictures and words, two weather bureau offices—one in the center of a large city and the other at a major airport.

A Visit to the Weather Bureau

TEACHING SUGGESTIONS
(pp. 242–250)

Background: This picture story provides a good way to reinforce many of the learnings derived from this unit. The youngster, by way of the story, has an opportunity to see real weather scientists at work. An excellent way to culminate this unit is to visit a local weather bureau with your class. After the visit, compare the activities taking place at your local weather bureau with those at the one pictured on these pages.

The following material will supply you with background information to aid you in answering your pupils' questions about the science of meteorology.

Meteorology is the study of the phenomena of an atmosphere. As such, it applies to the earth, to our planetary neighbors, and, in its broadest sense, to the sun itself. Meteorology encompasses an atmosphere's ingredients, motions, processes, and influences—past, present, and future. This science also involves the application of knowledge of the atmosphere to the solution of practical problems in business, industry, transportation, agriculture, defense, health, and communications. It is one of the most interdiscplinary of all sciences.

Meteorologists use the new tools of the electronic age to gain the understanding and the skill to probe atmospheric processes and motions. Meteorologists serve as "weathermen" at airports and local weather stations and as educators, consultants, writers, and businessmen. As a group, meteorologists are also chemists, physicists, mathematicians, oceanographers, radiometrists, geographers, hydrologists, astrophysicists, and engineers.

Because of the almost limitless breadth of meteorology, meteorological careers encompass many different specialities. However, these specialities frequently overlap, and many meteorologists will, in their lifetimes, work in more than one area of specialization.

It might be interesting to relate to your pupils some of the history of the United States Weather Bureau. It was not until the telegraph linked different parts of our country that people had the first practical means of sending information about weather conditions across the country. Before the telegraph, local weather observers were almost completely isolated from one another. If a weather observer in California sent information by pony express to Ohio, the weather usually arrived before the message.

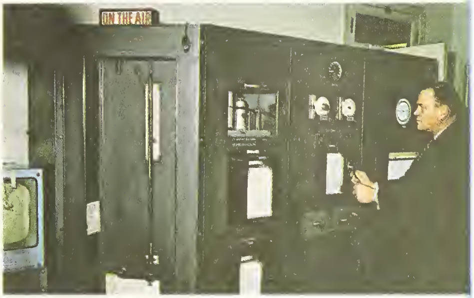
There is much activity in the weather bureau offices. Meteorologists work at their desks, at radar screens, and with special instruments.

There are meteorologists on duty twenty-four hours a day, seven days a week. Meteorologists make observations and record, report, and forecast the weather. Most of the meteorologists' observations are sent to the National Meteorological Center near Washington, D.C. At the Center, experts plot and analyze all the observations made on land, at sea, and in the air. From their maps and charts, meteorologists forecast weather conditions for the next two, three, four, or even five days. Some of the charts are analyzed and forecasts made automatically by high-speed electronic computers.

The radar room is connected to the radar dome on top of the seventy-story building in which this weather bureau is located.

This is the radar room. By watching the radar screen, the meteorologist can locate and identify approaching storms, clouds, and precipitation. From numbers on the outside circle of the screen and from the locations of the dots of light, the meteorologist can find the distances and locations of objects.

There is also a series of instrument racks in the forecast room. These racks contain various gauges and recording devices. Temperature, dew point, wind direction, duration of sunshine, and rate of rain and snow are some of the things measured. In this picture, you see the meteorologist-in-charge looking at the recorder to find the wind speed and direction and the duration of sunshine.



Below is the communication and duplicating room. In this room are many teletype machines, including a local public teletype.

In this room are also national weather teletypes, marine and hurricane teletypes, severe storm warning teletypes, and facsimile machines. There is a telephone information service for the maritime industry. A teletype sends the latest forecast to the telephone girl, who puts the forecast on a tape recording for the automatic public telephone. Because of the duplicating section, the office can rapidly print much information.

Weather forecasts are sent over the office's own broadcasting system.

In 1870, an act of Congress set up a national weather service. This service was authorized to prepare storm and flood warnings and to keep a file of weather records. In 1880, The United States Weather Bureau was established.

In the years since, the telephone, the teletype, radio, the facsimile transmitter, television, and satellites have helped speed up the exchange of reports. The following statistics will give you the scope of U.S. Weather Bureau observing and reporting activities.

The United States Department of Commerce Weather Bureau Reporting System includes reports from:

- 315 U.S. Weather Bureau Offices serving 297 localities
- 22 automatic meteorological observing stations
- 97 weather-surveillance radar stations
- 148 upper-air weather sounding stations
- 251 FAA stations reporting hourly for aviation
- 3,500 part-time stations reporting weather and river stages, on a nominal-fee basis

241 Supplementary Aviation Weather Reporting Stations (SAWRS), manned by airline or airport personnel
9,400 climatological and river-stage stations, whose observers serve without pay
121 part-time aviation and synoptic reporting stations, mostly on a fee basis
200 military stations that transmit reports to the Weather Bureau for public use
75 lighthouses and Coast Guard vessels reporting daily to the Weather Bureau for public use
1,000 merchant vessels reporting by mail
2,000 U.S. and foreign registry vessels transmitting observations by radio when underway in areas of western North Atlantic and eastern North Pacific waters
14 ocean upper-air weather stations—six fixed and eight mobile ship stations
2,000 foreign stations in accordance with international agreement

This is the public room, where the office's daily records are kept. In addition, the bureau maintains weekly, monthly, and yearly records of observations made at all weather bureau offices. State, national, and world records are also maintained. The public room is also equipped to serve as a briefing center for newspaper, television, and radio reporters during severe conditions.

A meteorologist briefs a weather reporter before her television program.

A few hours later, thousands of people see and hear the weather forecast on television. This information will help the people to plan their activities.

The city weather bureau office maintains its services for industry, business, shipping, agriculture, and the public. The weather services for domestic and international aviation are separate. They are handled by the bureau's airport station.

As you can see, the aviation weather station is also a busy, important place.

Facsimile machines provide copies of charts from the National Meteorological Center.

Teletypes continually receive information from many points in the country.

A meteorologist checks his observations with the supervising forecaster.

1,000,000	volunteer reporters helping Weather Bureau Offices to provide warnings of approaching tornadoes

Each year,

3,600,000	aviation weather reports from U.S. stations are collected by the Weather Bureau.
6,650,000	pre-flight weather briefings are provided to pilots.
1,700,000	aviation forecasts are issued covering area, terminal, and upper-air conditions over the U.S.
1,300,000	general public weather forecasts are issued.
75,000	river stage and flood forecasts are issued.
205,000,000	phone calls for weather information are answered by automatic telephone.
30,000	or more weather warnings, each having differences of sufficient significance to be of public concern, are issued.

The several types of observations are obtained through observations made on 63 kinds of instruments, totaling in all categories 58,000 instruments.

The United States Weather Bureau is a major bureau of the U.S. Department of Commerce. The primary mission of the Weather Bureau is to provide a national weather service for reporting the weather and climate of the United States and its possessions, and for issuing forecasts and warnings of weather conditions affecting the nation's safety and economic welfare. In carrying out this mission the Weather Bureau performs the following general functions:

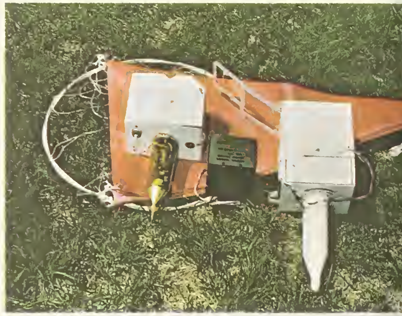
It observes, records, and reports on weather conditions and climate over all parts of the United States, its possessions, and adjacent areas.

It issues forecasts of weather changes, including advance warnings of severe or hazardous weather conditions, and provides special forecast and warning services to meet the needs of domestic and international aviation, forestry, and agriculture.

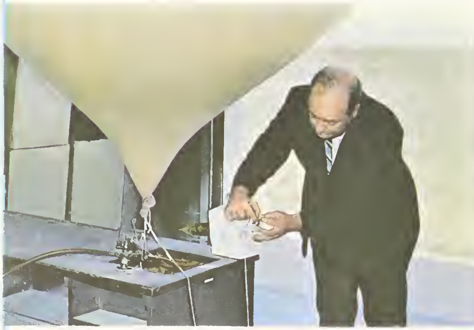
It observes, records, and reports on river stage and water-supply conditions and issues forecasts and warnings of floods.

It conducts basic and applied research essential to, or related to, these functions.

The weather bureau uses over 100,000 sounding balloons. Such balloons are used to carry radiosondes into the upper levels of the atmosphere to measure pressure, temperature, relative humidity, and wind. These data are collected in an area between the surface of the earth and the point where the balloon bursts. Then, the radiosonde parachutes to earth.

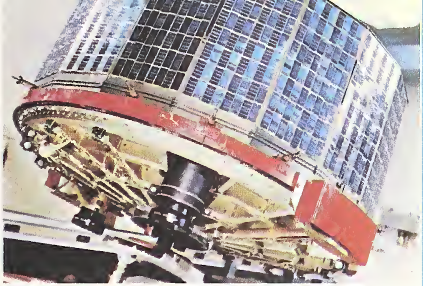


Above is the radiosonde, which has meteorologic instruments coupled to a radio transmitter and put a lightweight box.



A balloon is being inflated with helium, and a radiosonde is being attached.

The balloon, with the attached radiosonde, is released into the air.



The radiosonde transmits to a ground receiving set. On the ground the data are printed on a recorder chart. The data are studied as the balloon rises higher into the atmosphere. When the balloon reaches the height at which the air pressure inside it is far greater than the outside air pressure, the balloon bursts.

The data from the radiosonde are transmitted over a national teletypewriter system in coded form. Then, various communication systems send the information to all parts of the world. The data are also recorded for use in various weather research projects.

To meet the needs of the Space Age, meteorologists now look to rockets and satellites for data from places in the atmosphere far beyond those reached by radiosonde balloons.

The *Tiros* and other satellites are providing meteorologists with pictures of and data about the atmosphere. This information will greatly aid weather forecasting.

At this station, there is a *Tiros* weather satellite tracking system.

The scope of the Weather Bureau's research and development activities ranges from small-scale studies in micrometeorology and the physics of clouds and precipitation to global studies of the physical processes and circulation of the earth's atmosphere. Emphasis is placed on investigations directed toward improving methods of weather prediction, especially those related to developing improved methods of forecasting severe storms such as hurricanes, tornadoes, intense thunderstorms, and blizzards.

The Weather Bureau also publishes information resulting from meteorological research activities that it fosters, promotes, develops, or supports. International exchanges of weather science information is also promoted and coordinated by the Weather Bureau.

Because of the many thousands of reporting sources, a code was agreed on, in which certain numbers and symbols represent different weather conditions. In any country, you can find charts of this code in weather stations. Weathermen speak a common, international language.

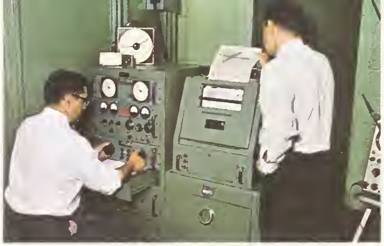
A coded message from a teletype machine might appear on tape as:

405 83220 12716 24731 67292 30228 74542

These numbers have the following meanings:

405—Number of the Washington station.
8—Sky is completely covered with clouds.
32—Wind is blowing from the northwest.
20—Wind speed is 20 knots (23 miles an hour).
12—Visibility is 12/16 or $^{3}/_{4}$ of a mile.
71—A continuous light snow is falling.
6—It had rained previously.
247—Barometric pressure is 1024.7 millibars.
31—The temperature of the air is 31° F.

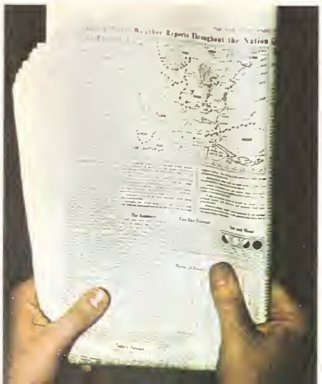
The other numbers tell the types of clouds present at various levels, when precipitation started, how many inches fell, which way and how fast the pressure is changing, and other facts.



Using the machine, the operator turns the tracker antenna to follow the satellite.

The *Tiros* satellite radios pictures back to earth. Here, you see the supervising forecaster looking at a picture that has just been developed.

A special weather bureau airport office briefs each pilot on general weather conditions and on the kind of weather he may expect on his trip.



The next time you hear a weather report on the radio, see and hear it on television, or read it in your local newspaper, remember that thousands of men and women work day and night to forecast the weather. Forecasts not only help you to plan your daily activities but also help people to protect lives and property.

Weather and the International Geophysical Year

The **International Geophysical Year** (jee-oh-FIZ-ih-k'l), known simply as IGY, which took place during 1957-58, greatly aided meteorologists. For the first time, instruments were placed in satellites that circled the earth. These instruments recorded what it was like in the atmospheric layers and in outer space. Scientists then had better measurements of the sun's rays. They also had measurements of the heat rays that were reflected back into the atmosphere from the earth. Scientists were able to decide more accurately when the earth gained and lost heat. Scientists who were interested in world-wide weather were able to compare measurements recorded by instruments on the satellites with their information about melting ice sheets, temperatures over the oceans, and other weather conditions. Satellites also enabled scientists to spot **hurricanes** (HUR-ih-kaynz), which are very strong storms, early in their formation.

As part of the IGY program, many new weather-observation stations were built. More than 55 new stations were established in Antarctica alone. Before the IGY took place, there were not even enough data on the Southern Hemisphere to allow scientists to draw a weather map. During the IGY, scientists found that the Southern Hemisphere's weather was much colder than scientists had thought it was, except when storms blew in with warm air from the ocean. As a result of the IGY, scientists learned that these storms play a very big part in the making of the weather in this area.

Perhaps the most important information gained during the IGY was that the atmosphere contains a fixed amount of air, which gains heat in some places and loses it in others.

Weather Satellites

Weather scientists are now receiving pictures, taken in space, of the earth's clouds. These pictures are taken by weather satellites and sent back to earth by television.

Tiros I was the first United States "Weather Eye" satellite to be sent into space. This satellite was the first weather station to be placed in orbit. Two television cameras sent back pictures of the earth's cloud cover to weather stations on the ground. The cloud-cover pictures helped meteorologists to understand and forecast the weather better.

Tiros III gave scientists the first picture of a hurricane as seen from space.

TEACHING SUGGESTIONS
(pp. 251–252)

LESSON: Why is international cooperation among meteorologists important?

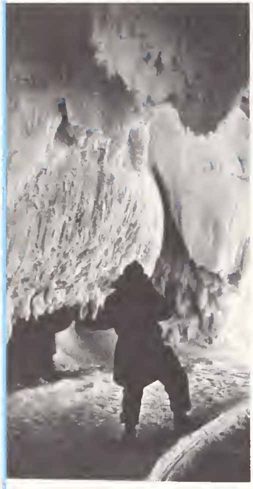
Background: There are two basic reasons for international cooperation on scientific research. First, the cost of research (and development of instruments to assist research) is extremely high. Second, many questions are too broad to be answered by information available within one nation alone.

It was during the 19th century that various religious groups, government commissions, and scientific societies began to cooperate with each other on an international scale. The abolition of slave trade was an international undertaking, for example.

In science, insofar as it relates to this lesson, international cooperation began with the Polar Year of 1882–1883, when fourteen nations jointly established stations in the Arctic to study the arctic weather, the earth's geomagnetic field, and the origin of the aurora borealis. Fifty years later, in 1932–1933, a Second Polar Year was formed. Thirty-three nations cooperated in this program, in which the origin and effects of the ionosphere were studied.

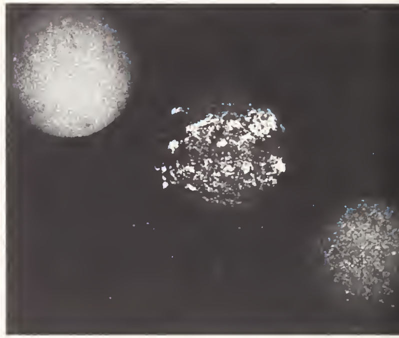
These two predecessors of the International Geophysical Year (which extended originally from July 1, 1957, to December 31, 1958) set a pattern for international cooperation. The idea for the IGY was first proposed in 1950 and by the time final plans were completed, sixty-six nations had agreed to take part. The years 1957–1958 were chosen because the sun's sunspot activity would be at a maximum. The major problems studied included the nature of the earth's structure, the structure of the ocean basins and the major patterns of flow of ocean currents, the growth of the polar ice caps and their effect on the climate of the world, the world pattern of air flow, the influence on the earth of the sun's magnetic field and of sunspots, and the exploration of the upper atmosphere.

Some of the major discoveries made were of the Van Allen radiation belts around the earth, the fact that the earth has bulges around the Southern Hemisphere (that is, the earth is very slightly pear-shaped), and that the polar ice caps have been gradually melting over the last 50 years, raising the general level of the oceans. If this warming trend continues, New York and San Francisco may be under water in the years to come.

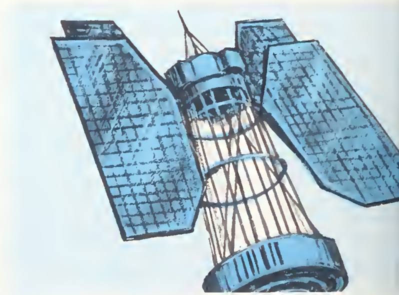


INTERNATIONAL SCIENCE PROGRAMS

During the IGY program scientists observed weather conditions in many parts of the world. On the left, a scientist studies the inside of a cave formed by the wind and the movement of ice. Below, a scientist reads a gravimeter to study the composition of the earth's crust beneath the ice. At the bottom of the page, you see an explosion made to determine the thickness of ice. How are such explosions used to make measurements?



An outgrowth of the IGY program was the International Years of the Quiet Sun (IQSY). IQSY's goal was to compare data gathered during the sun's quiet period with those from the IGY, in 1957-58, when solar activity was at its highest level since planned scientific observations began, 200 years ago. Above, the sun's quiet period (1954) is shown at the left. The middle view shows the sun during the active period in 1958. Above right is a view taken in 1964 showing the sun in its quiet period again.



Several *Tiros* satellites now circle the earth collecting information about weather conditions.

Keep abreast of the latest weather satellites and discuss them with the class to show continued scientific research.

There are now several Tiros satellites circling the earth and "keeping an eye" on the weather. A later weather satellite called Nimbus has also been sent into orbit to televise changing weather conditions and transmit these data back to central weather-forecasting stations.

Machines to Predict Weather

Meteorologists now use mathematics to forecast patterns of atmospheric pressure. Their method is known as "numerical weather prediction."

Electronic machines known as **computers** (kum-PYOO-terz) are "fed" information about the weather. These computers use this information to develop prediction charts. Many of these charts are more accurate and more quickly prepared than the charts made by skilled weather forecasters. The charts are used by meteorologists to prepare their final weather forecasts.

Using computers, forecasters can now make forecasts in terms of probability. Perhaps you have heard a forecaster on television or radio predicting a 65 per cent probability of showers in the afternoon in your city. The figure "65" is not the result of a guess. The meteorologist knows what conditions produce rain. He will put into a computer information—about such matters as temperature, dew point, clouds, and time of day—about those days in the past when it has rained in the afternoon. This information is stored in the computer. Then, on a particular day, he will put in information about those conditions on this particular day. The computer makes lightning-fast calculations, involving a comparison of the present conditions with the stored information. The computer will come up with the information that 65 out of 100 days in the past when the present conditions existed your city had rain.

Computers are only as good as the information that is put into them. As weather-data gathering improves and weather statistics are quickly analyzed with the help of computers, forecasts will be made with probabilities that are closer to 100 per cent.

The United States Weather Bureau has a numerical weather-prediction center, which it and the United States Air Force use. The center is part of the National Meteorological Center in Maryland. Forecasts obtained from computers there are sent to forecasting stations throughout the country.

Weather forecasting has advanced rapidly in the past several years. But there are many more advances to come in the years ahead.

TEACHING SUGGESTIONS
(p. 253)

Background: The "Numerical Weather Prediction" system has been operating since the late 1950's and has greatly improved the accuracy of weather prediction despite severe limitations.

A large number of observations are sent to Washington, D.C., at stated intervals. These may include, at a given time, 1,500 surface reports (from stations on the surface of land or sea), 400 reports about the upper air (from radiosonde and weather planes flying regular patterns), and about 150 reports from commercial planes (in-flight reports at regular 6-hour intervals). These reports are coded and fed into a computer. The computer produces a numerical value for each section of a particular predetermined grid map of the United States.

At present, only air movements and air pressures are covered. Inclusion of data on water content and movement is too complicated to be handled by this method yet. The present value of the system lies in the data it gives the forecaster.

TEACHING SUGGESTIONS
(pp. 254–257)

Background: Assuming that a local newspaper in your community publishes a daily weather map similar to the map shown on page 241 of the text, the pupils might like to try a simple kind of weather forecasting on their own.

Have the pupils clip the weather map from the newspaper for 3 or 4 days. In class, discuss the general points of interest in the maps as they relate to your own community. Identify the areas of high and low pressure and the weather fronts that lie between.

When you have thus introduced the weather maps and made sure that the pupils understand the meanings of the symbols used, the pupils can use the maps themselves to forecast changes in the pressure areas and their probable effects on the weather fronts. Have the pupils pick a particular high- or low-pressure area along the west coast of the United States, as shown on a weather map. Pupils should follow that pressure area as it moves across the map day after day. On a sheet of tracing paper (or onionskin paper) they should trace lightly an outline of the United States (or the edge of the map) and mark the *center* of the pressure area.

PATHFINDERS IN SCIENCE

Robert M. White

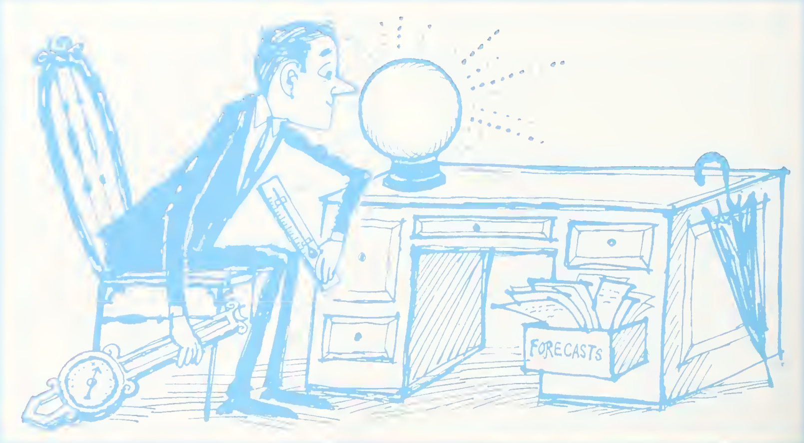
(1923–   ) United States

Not long ago, cartoonists poked fun at the weatherman by drawing him with a thermometer in one hand and a barometer in the other while he looked through a crystal ball. But the picture has changed. The weatherman is now thought of as a highly trained scientist—a member of a dedicated team of scientists who work day in and day out to serve us.

In charge of this team is Dr. Robert White, who became Chief of the United States Weather Bureau in 1963. Dr. White's preparation for his important post included several years of service as a captain in the meteorological section of the United States Air Force and four years with a weather research center.

As a boy in Boston, Robert White liked to explore the nearby woods, rocks, and waters. He thought he would become a geologist. However, at college he had a chance to work at a weather observatory and decided to become a meteorologist.

In 1959, Dr. White became head of a weather research center. One of his achievements was the development of new ways to broadcast weather forecasts.



How and why did Dr. White change the way forecasts were made? To understand, you must first know something about Dr. White's ideas and beliefs about man and nature.

Dr. White believes that man is still not in control of nature. Man is a part of nature, and so he must find a way to live in harmony with the rest of nature.

It is important for people to act if there is danger in the environment. For example, if there is a chance that a violent storm will occur, not acting can result in much suffering. When hurricane warnings are given in Florida, home and store owners board up windows and doors to prevent injury and breakage. People living near the coasts move to safer places until the storm is over.

Dr. White believes that people listen to warnings from trustworthy sources. He handled the broadcasting of forecasts by having the forecaster say something like this: "The chances of rainfall through tonight are two in ten, rising to five in ten by morning and to ten in ten by tomorrow night." This kind of forecast lets people know the degree of uncertainty of the forecast, as the weatherman himself knows it. When people heard these forecasts, the people took action to save property and lives when there was a likelihood of danger. Since Dr. White became chief of the United States Weather Bureau, many cities in the country have been broadcasting their forecasts this way.

"Meteorology," says Dr. White, "is on the threshold of a true revolution. The forecasts of specific weather that interest us as ordinary people—whether it will rain tomorrow or not—still need a lot of improvement. But a revolution is taking place in forecasting, nonetheless. We have moved in recent years from the era of weather forecasting as an art into a new era of meteorology as an applied science. We've already come a long way in a short time."

Dr. White, a leader in this revolution in meteorology, is well equipped to be one.

Thereafter, on the weather map for the following day, they should mark a second point on the tracing paper that represents the center of the chosen pressure area. On the third day, they should mark the center of the pressure area in the same way. In this way, over the course of a few days, they can follow the weather pattern as it changes.

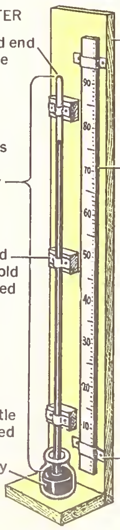
Have the pupils connect the points on their maps to show the direction and speed of the pressure area as it travels forward. See if they can predict where the pressure area will be on the day after, and the day after that, etc.

As an alternative to this individual activity, the forecasting can be done by the class as a whole on a large map of the United States, over which a sheet of transparent acetate has been fastened. Choose a pupil who is particularly neat and accurate to draw on the acetate with a grease pencil the weather map as published in the daily newspaper. Then each day thereafter as the weather map changes, the daily movements of the high and low pressure areas can be marked on the acetate and the pupils can follow these changes and attempt to predict how the pressure centers and the weather fronts will move from one day to the next.

ADDITIONAL ACTIVITIES:

Pupils might enjoy making the following weather instruments.

A simple mercury barometer. Fill an ink bottle about 1/2 full of mercury. Using an eyedropper, fill a glass tube with mercury. Make certain all air bubbles are out of the mercury. Stretch a piece of thin rubber from a balloon over the open end of tube. Pull it firmly along the sides of the tube so that the mercury will not drop out when the tube is inverted. After the tube is in position, remove the piece of rubber.



Volunteer Weather Observers

Every day over 12,000 voluntary observers record the weather in their parts of the United States. Their work includes measuring rainfall, snowfall, and the high and low temperatures for the day. They record these measurements and mail them to the nearest weather bureau.

The weather bureau uses these records to answer the many requests received from people all over the country who want weather information. The weather records of the volunteers are also used in planning hospitals and schools. Weather records are used as a basis for paying insurance claims, weighing evidence in criminal trials, deciding whether or not to buy land in an area, surveying community airport redevelopment, delivering fuel supplies, selecting which crops to plant, planning vacations, and even for deciding whether or not to air-condition a salesman's car.

Volunteer workers are a great help to the weather bureau. Without the help of these volunteers, many of the weather-information needs of the citizens of the United States would not be met.

Using What You Have Learned

1. If you can find a weather map in a newspaper, you can try forecasting the weather. First examine the weather map. Locate the highs, lows, and fronts. From this information, try to forecast the weather on your own. Now check your forecast with the one that is printed in the paper. Make forecasts for several days. Keep a record of them to see how well you do. Compare your record with the records of some of your classmates.

2. Newspapers print various kinds of weather maps. See how many kinds you can collect. You might write to friends in other areas for weather maps. Compare these maps with

ones from your own area. How does each map show warm and cold fronts? How does each show winds, temperature, and precipitation? How does each show highs and lows?

3. Explain why it is very difficult to forecast the weather without knowing what kinds of weather the other parts of the country are having.

4. Make a poster to show cold air masses, warm air masses, a cold front, and a warm front. On your poster show the kinds of weather in a cold air mass and a warm air mass. Then show the kinds of weather along a cold front and along a warm front. Put the poster on a wall in your classroom. When there is a change in the weather where you live, use your poster to explain whether it was caused by a cold front or a warm front moving into your locality.

5. If you want to learn the meanings of the weather symbols given on the map on page 241, here is a good way to do so. Draw each symbol on a small card. Include those symbols that stand for the different wind speeds. On the back of each card, write the meaning of the symbol. See how many symbols you can understand without looking at the backs of the cards.

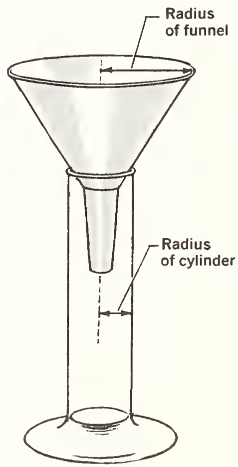
6. You or a group of pupils may want to act as meteorologists for your class. You can set up a weather station. To do this, you will need the following instruments:

thermometer	air-speed chart, or anemometer
barometer	wet-bulb and dry-bulb thermometers or a hair hygrometer
cloud charts	rain gauge
wind vane	
visibility chart	

Decide at what times you will make your observations and how you will keep your records.

A rain gauge. Put a funnel into a flat-bottomed glass container, such as a graduated cylinder. To determine the depth of water in the cylinder equivalent to 1 inch of rainfall, divide the square of the radius of the top of the funnel by the square of the radius of the cylinder. For example, if the top of the funnel's radius is 3 inches, and the radius of the cylinder is 1 inch, it will take 9 inches of rain in the cylinder to equal 1 inch of actual rainfall.

RAIN GAUGE



TEACHING SUGGESTIONS
(pp. 258–259)

Background: These two pages constitute a review of the concepts and terminology introduced in this unit.

What You Have Learned: This is a summary of the entire unit, with new words in boldface type.

Checklist of Science Words: Remind the pupils that there is a *Dictionary of Science Words* on pages 358–364. They should consult this dictionary whenever they are unsure of the precise meaning of a word.

Name the Layer:

1. Stratosphere
2. Troposphere
3. Exosphere
4. Troposphere
5. Tropopause
6. Ionosphere
7. Stratosphere

Tell the Difference:

1. Highs (areas of high pressure) usually mean good weather. Lows (areas of low pressure, usually because of high moisture content) generally bring bad weather.

2. A maximum thermometer is so constructed that the mercury column does not contract but remains at the highest point reached during its expansion. (Fever thermometers are maximum thermometers.) A minimum thermom-

WHAT YOU KNOW ABOUT

Probing the Atmosphere

What You Have Learned

The air around the earth is called the **atmosphere.** The atmosphere is divided into five layers: the **troposphere,** the **tropopause,** the **stratosphere,** the **ionosphere,** and the **exosphere.** Weather takes place in the atmosphere near the earth. Weather scientists, or **meteorologists,** forecast weather by using **thermographs** to measure air temperature and **barometers** to measure **atmospheric pressure.** Other instruments used in weather forecasting are **wind vanes, rain gauges, transmissometers,** and **anemometers. Radar,** weather balloons, **radiosondes,** satellites, and **computers** are also used. The United States Weather Bureau has a numerical forecasting center that uses computers to develop prediction charts. These charts are sent to forecasting stations throughout the country. The charts are more accurate than charts made by skilled weathermen.

Meteorologists observe the clouds to obtain information about the weather. Clouds provide much information about weather changes. A cloud forms when water evaporates into the atmosphere and becomes water vapor. Air is constantly moving, and some of that movement is upward. The air becomes cooler away from the earth. Some of the water vapor changes back into liquid. It is then called a cloud. **Cumulus clouds** may indicate wind, driving rain, hail, or tornadoes. **Cirrus clouds** may mean bad weather is ahead. **Stratus clouds** mean that it will soon rain.

Thousands of meteorologists using many kinds of instruments work day and night to forecast the weather. Volunteer observers help the weather bureau keep weather records of every section of our country.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

anemometer	jet stream	radiosonde
atmospheric pressure	meteorologist	relative humidity
computer	millibar	stratosphere
hygrometer	precipitation	tropopause
isobar	radar	troposphere

Name the Layer

Write the numbers 1 to 7 in your notebook. Next to each number write the layer of the atmosphere described in each sentence below.

1. The layer in which there is almost no weather.
2. The layer in which weather takes place.
3. The highest layer of the earth's atmosphere.
4. Nearly all winds and clouds are found in this layer.
5. Wind currents in this layer are called jet streams.
6. This layer is above the stratosphere.
7. Jet pilots like to fly in this layer.

Tell the Difference

1. highs—lows
2. maximum thermometer—minimum thermometer
3. troposphere—tropopause
4. cirrus clouds—cumulus clouds
5. isobars—millibars
6. cold front—warm front

eter is so constructed that the mercury column does not expand from the lowest point to which it has contracted.

3. The troposphere is the layer of atmosphere nearest the earth. It is about 5 miles thick above the polar regions and 11 miles thick above the equator. The tropopause is the thin layer of atmosphere between the troposphere and the next layer, the stratosphere.

4. Cirrus clouds are high, fast-moving, thin wisps of clouds made up of ice crystals. Cumulus clouds are light, puffy piles of water droplets caused by swift-rising currents of warm, humid air.

5. Isobars are lines drawn on a map connecting points of equal atmospheric pressure (all points on any one line have the same pressure). Millibars are units of measure of atmospheric pressure (30 inches of mercury is equivalent to 1,016 millibars).

6. A cold front is the line of contact of two air masses when the colder mass is moving forward to displace the warmer one. A warm front is the line of contact of two air masses when the warmer one is moving forward to displace the colder.

TEACHING SUGGESTIONS
(pp. 260–261)

Background: These pages reinforce the concepts presented in the unit by suggesting activities that extend the pupil's ability to apply the learnings derived from the unit.

Name the Clouds:

Bottom: Stratocumulus
Center: Cumulus
Top: Cirrus

Can You Tell?

A hygrometer measures relative humidity.

A barometer measures air pressure.

A wind gauge measures wind velocity.

A balloon collects data in the upper atmosphere.

Radar detects approaching storms.

A weather satellite is used to make photographs of clouds and storms over wide areas of the earth.

You Can Read: Additional books for the children include:

Air, by Irving and Ruth Adler (Day, 1962).

Weather in Your Life, by Irving Adler (Day, 1959).

YOU CAN LEARN MORE ABOUT

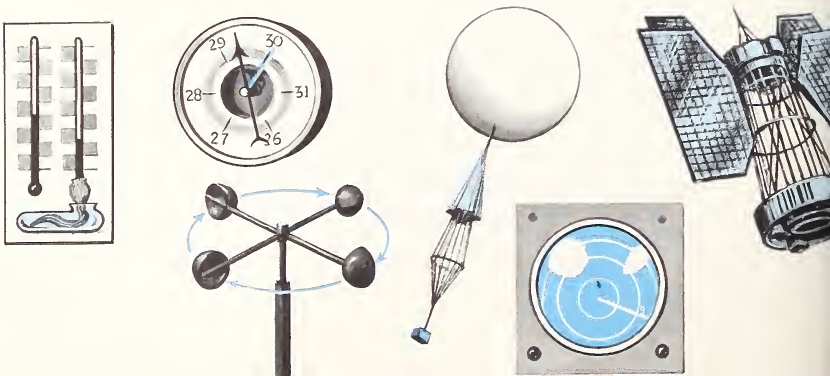
Probing the Atmosphere

Name the Clouds

What kinds of clouds do you see in the picture?

Can You Tell?

How do the instruments below help the meteorologist predict the weather?



You Can Visit

A weather station is a fascinating place to visit. Perhaps there is a United States Weather Bureau office near your home. At a weather station you will see meteorologists at work. And you will see many of their instruments.

Look again at the pictures of the United States Weather Bureau in action on pages 243 to 250. How is the weather station you visit like the one in the pictures? How is it different?

You Can Read

1. *Hurricanes, Tornadoes, and Blizzards,* by Kathryn Hitte. Introduces some basic principles of air and winds. Explains how, why, and where violent storms take place.
2. *Exploring the Air Ocean,* by Frank Forrester. A history of the science of meteorology.
3. *The Wonderful World of the Air,* by James Fisher. Very well illustrated story of the atmosphere.
4. *Weathercraft,* by Athelstan F. Spilhaus. A guide to making a home weather station.
5. *Our Changing Weather,* by Carroll and Mildred Fenton. Shows how meteorologists forecast the weather and gives hints on how you can make forecasts.

Snow, by Thelma H. Bell (Viking, 1954).

Thunderstorm, by Thelma H. Bell (Viking, 1960).

Skywatchers: The U.S. Weather Bureau in Action, by William Bixby (McKay, 1962).

Our Changing Weather, by Carroll and Mildred Fenton (Doubleday, 1954).

Exploring the Air Ocean, by Frank Forrester (Putnam, 1960).

Exploring the Weather, by Roy A. Gallant (Garden City, 1957).

Hurricanes and Twisters, by Robert Irving (Knopf, 1955).

Weathercasting, by Charles and Ruth Laird (Prentice-Hall, 1955).

The Ways of the Air, by Roger Pilkington (Criterion, 1962).

Everyday Weather and How It Works, by Herman Schneider (Whittlesey, 1961).

Weathercraft, by Athelstan F. Spilhaus (Viking, 1951).

The Hurricane Hunters, by Ivan R. Tannehill (Dodd, 1955).

Probing the Atmosphere, by Louis Wolfe (Putnam, 1961).

The Wonders of the Atmosphere, by Louis Wolfe (Putnam, 1962).

KEY CONCEPTS

Key Concept 1. Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

Key Concept 4. All objects in the universe and all particles of matter are constantly in motion; man has discovered and stated the laws governing their motion.

Key Concept 6. There is a basic tendency toward stability or equilibrium in the universe; thus, energy and matter may be transformed, but the sum total of matter and energy is conserved.

Key Concept 9. The scientist has developed measures of space, time, and matter so that he can communicate explanations that are reproducible and make predictions about events in the natural environment.

CONCEPTS:

1. Man's efforts to rise above the earth have a long and interesting history.
2. Scientists have used animals and men in studying effects of high altitudes on living things.

8

Other concepts appear under "Learnings to Be Developed" in each lesson found in the Teaching Suggestions.

Probing Outer Space

The Challenge of Outer Space
Rockets Explore Space
Men Venture into Space

3. For every action (force) there is an equal reaction (opposite force).
4. To launch objects from the earth, a force greater than gravity must be obtained.
5. When a satellite has a speed of 5 m.p.s., its falling motion toward the earth corresponds to the curvature of the earth.
6. Satellites and space probes are used in collecting evidence about outer space.
7. Astronauts in space experience unusual conditions of acceleration and weightlessness.

PROCESSES:

- Questioning—Page 270.
- Observing—270, 273, 274, 275, 277, 279, 280, 287, 293, 296, 299, 301, 305.
- Experimenting—273, 274, 275, 277, 279, 280, 287, 293, 296, 299, 301, 305.
- Comparing—270, 273, 274, 275, 277, 279, 280, 287, 293, 296, 299, 301, 305.
- Inferring—273, 274, 275, 277, 279, 280, 287, 293, 296, 299, 301, 305.
- Measuring—273, 274, 275, 276, 277, 279, 280, 287, 293, 296, 299, 301, 305.
- Selecting—270, 288, 305.
- Communicating—270.
- Demonstrating—270.
- Explaining—265, 274, 278, 279, 280, 288, 299, 301.
- Hypothesizing—274, 276.

TEACHING SUGGESTIONS
(pp. 264–265)

● **LESSON:** How long have men dreamed of flying? What forms have these dreams taken?

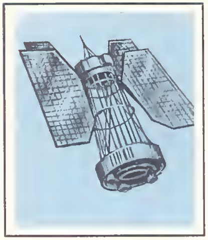
Background: This introductory section examines the human drive —curiosity—that has made man speculate about the stars since the most ancient days. A few of the practical problems are pointed out, and some of the naïve theories of the past—from Greek legend to modern science fiction —are discussed briefly. Outer space is intrinsically fascinating to children. If possible, the teacher should bring in photographs taken by the latest lunar or interplanetary probe.

Learnings to Be Developed: Men have speculated about flying through space for a long time.

Developing the Lesson: Read the first section, and then discuss it.

Point to the picture of Daedalus and Icarus (page 264, left) and tell the legend of the two early flyers.

"Daedalus and Icarus, his son, were men of ancient Greece who wanted to escape from the Labyrinth, in which they were imprisoned. So they made themselves wings of feathers and wax, and flew up into the sky from the



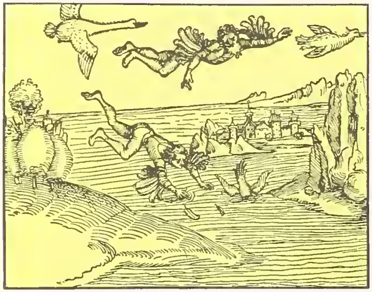
Why do men want to explore space? How many reasons can you think of? Do you think that perhaps one of the reasons is that men are curious to find out what is in space? Curiosity is the desire to find out. Curiosity often leads men to experiment, to discover, and to invent. Curiosity is the key to finding out.

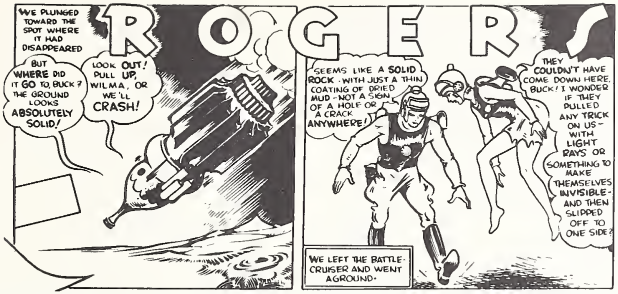
The Challenge of Outer Space

Curiosity has led men to discover methods of preventing and treating disease. It has led them to find new ways in which to harness the energy of the sun. It has made their everyday living safer and more comfortable. And now the desire to find out more about the universe has led men into space.

Men hope to reach the moon and the planets someday. How soon depends on how quickly scientists solve many problems. Scientists must first discover how to keep men alive in space. In this unit, you will learn about this and other problems that scientists must solve before men can reach the moon.

Man has long dreamed of flying. A Greek myth tells of Daedalus and Icarus, who used wings made of wax and feathers to try to fly. At the right is a flying machine designed by Leonardo da Vinci in 1500. Find out about early attempts to fly.





In 1929 space travel was science fiction. Today we are only a few years away from the time when men will land on the moon and possibly Mars and other planets.

For ages men have dreamed of traveling to the moon and to the planets. But it is only since the development of powerful rockets that man has been able to soar beyond the earth's atmosphere.

The first questions man had about space had to do with the atmosphere: Is all the space between the earth, the moon, and the stars filled with air? Is the air above the earth cold or hot? The first space explorers had to answer many questions like these. But long before real explorations were possible, voyagers in story and legend traveled into space on giant birds and in spacecraft. Look at the pictures above from a popular cartoon strip called "Buck Rogers in the 25th Century." This comic strip first appeared in 1929, when most men thought space exploration impossible. Stories such as these entertain readers and make them more curious.

Balloons in the Air

While some dreamed of space travel, others took the first steps toward exploring space.

By 1783, the Montgolfier (mon-gol-fee-AY) brothers of France had built a huge balloon of paper and linen. One day, a man climbed into the **gondola** (GON-duh-luh) below this balloon. Other men built a fire below the open balloon. The air inside became hot. Many people thought the balloon would burn. Instead, it slowly rose into the air, carrying the balloonist many feet above the earth.

Can you explain why the balloon floated into the atmosphere? Would the warm air in the balloon have more or less weight than the same amount of air outside the balloon?

Not everyone was satisfied with hot-air balloons. The fires were dangerous,

Labyrinth. But Icarus flew too close to the sun, and the wax in his wings melted. He fell to his death."

Develop the idea that science can be dangerous when the scientist is rash or hasty. "Today we proceed more cautiously than Daedalus and Icarus. We experiment, we test, we check, and we double check."

Point out that Leonardo's flying machine (page 264, right) did not work. Leonardo designed the machine to imitate the wings of birds. He did not know that man is too heavy to propel himself through the air in this manner.

- *There are no flying birds that weigh as much as man. Why?* (Because they would not be able to fly if they did weigh so much.)

Follow-Up: Have the children think of other stories they have read about people who could fly—there are an astonishing number of them in the fairy tales and legends of the world.

ADDITIONAL ACTIVITIES

Have the pupils observe the flight of a bird.

- *How is it different from that of an airplane? How is it the same?*

TEACHING SUGGESTIONS
(pp. 265–267)

LESSON: What were the first balloons like?

Background: Between 1783 and 1927, balloons were invented and improved. Balloonists gathered data about the atmosphere and its effects upon man. This knowledge helped lay the groundwork for flights into space.

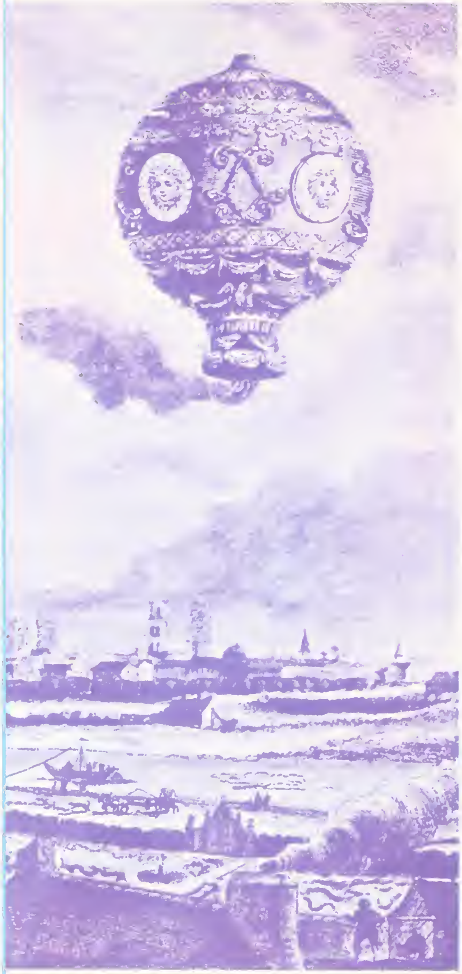
Learnings to Be Developed:

Balloons can be filled with hot air, with hydrogen, or with any other gas lighter than air.

Men must protect themselves from the lack of heat and oxygen in space.

Developing the Lesson: Have the children read the section "Balloons in the Air" and then discuss it. Explain that a gondola is a basket suspended beneath the balloon. Men ride in the gondola.

- *Can you tell how the scientists who improved the balloon thought?* (They thought: It is the hot air that causes the balloon to rise. That is because the hot air is lighter than cold air. *Anything* lighter than air will make a balloon rise. Do we know of anything lighter than air?—hydrogen gas.)



and sometimes the balloons burned. Those that did rise remained in the air for only a short time. When the air in the balloon cooled, the balloon returned to earth. Unheated air was too heavy to keep the balloon in the air.

Scientists searched for lighter gases to use in balloons. Nitrogen and oxygen, the main gases in the atmosphere, were much too heavy. Finally, it was decided to use hydrogen, the lightest known gas. Hydrogen is only one-fourteenth the weight of air.

Balloons filled with hydrogen floated higher into the atmosphere. These balloons could be controlled by releasing some of the gas. Can you tell how?

Exploring in Balloons

As balloons went higher, men asked questions about traveling above the earth: What happens to a man's body in a floating balloon? How does the atmosphere above the earth compare with air near the ground? No one knew, but some men started to find out.

On a January morning in 1793, people in Philadelphia watched the first balloon in the United States rise to 5,000 feet. The pilot of the balloon made a few tests for some scientists. One medical doctor wanted to know if the air at 5,000 feet is different from the air on the

ground. When the pilot reached that altitude, he filled bottles with air and brought them back to the doctor for study.

Another medical doctor wished to find out if altitude affects the rate of heartbeat. The pilot tested his own pulse at 5,000 feet. He had a pulse rate of 92 times a minute. On the ground, the rate had been 84 a minute. Was it the altitude that affected his heartbeat? Or was it the excitement of the flight? What do you think?

Balloon flights continued, and scientists wanted answers to other questions. How high could a man rise in an open balloon? In what ways does air temperature change as altitude increases? People had long known that it is cold on top of high mountains and that the air is very thin. Scientists believed that the atmosphere became colder as altitude increased. Was this really so? The only way to find out was to rise even higher.

In 1875, three men in an open gondola reached 25,000 feet—much higher than anyone had gone before. The men kept records as the balloon climbed. On the ground, the air temperature was 70 degrees. As the balloon rose, the air became colder. The balloonists found that the temperature dropped about 1 degree for each 300 feet of altitude. Using this information find what the air temperature was at 24,000 feet.

As the balloonists went higher, they became very sick. One of them managed to open the control valve, and the balloon started down. None of the men lived to tell what had happened, but their records were recovered. From these records, scientists learned that the explorers had suffered from cold and from lack of oxygen. These records helped scientists to prepare for higher flights.

In 1927, an American balloonist, Captain H. C. Gray, rose into the stratosphere to 44,000 feet. As he rose, he took careful temperature measurements. At 31,000 feet, he found that the temperature was 32 degrees below zero. At 40,000 feet, it was 28 degrees below zero. It seemed that, as the altitude increased above 31,000 feet, the air became warmer. This new evidence puzzled scientists. They had believed that the air would steadily become colder, but now they were not sure.

More flights were made. Again, a warmer layer of air was found at about 40,000 feet. But above that level, the temperature became colder and colder. Now scientists had a better idea of temperature in the atmosphere high above the earth.

- *Are there any gases lighter than hydrogen? Are any possible?* (No. Hydrogen is the lightest element, consisting of a single proton and a single electron.)
- *What did men find when they rose into the atmosphere?*

The next section, "Exploring in Balloons," answers this question.

- *Had man ever been as high as 5,000 feet before 1793?* (Often. Mountain climbers had gone at least three times as high.)
- *Then why not simply climb a mountain and perform the experiments?* (Because the balloon at 5,000 feet was free from most of the effects of the ground. In scientific observations you try to control as many factors as possible. Often this is done simply by eliminating them.)
- *Did the pilot really fill the bottles? Think carefully.* (No, the pilot emptied them. The air at 5,000 feet is thinner than the air on the ground. When the pilot took the caps off the bottles, the thicker air inside mixed with the thinner air outside until they were both the same. In filling the bottles, he emptied them!)

TEACHING SUGGESTIONS
(pp. 268–270)

● **LESSON:** What did balloonists find out when they rose to great altitudes?

Background: The lesson tells of improvements in the design of balloons—especially the closed gondola—that made explorations at altitudes of more than 120,000 feet possible. There at the edge of space, cosmic rays were more numerous, air was lacking, and the cold was intense. Could life survive in this extremely hostile environment? Scientists experimented, and found that it could, if suitably protected.

Learnings to Be Developed: The stratosphere, above the troposphere, was explored by ballonists.

Developing the Lesson: Have the children read the section "Exploring the Stratosphere." When they have finished, ask:

- *Why did Professor Piccard use a special closed gondola?*
- *What did he find at 51,000 feet?*

Explain that cosmic rays are mainly extremely energetic particles that come from outside the solar system. Even today we aren't completely sure where they come from or why they have so much energy.

Auguste Piccard prepares to close the lid on the gondola of his balloon and rise into the air.

Exploring the Stratosphere

Men were still a long way from reaching outer space. They had explored far above the earth and learned many new things, but these flights were dangerous. There were too many problems—intense cold, lack of oxygen, frozen instruments. They could go no higher in open balloons.

In 1931, a Swiss scientist named Auguste Piccard (pee-KAHR) invented a special closed gondola which solved these problems. It was shaped like a ball and was very light. Windows were placed in the walls. Inside the ball were tanks of air and scientific instruments. The balloonist also carried a camera. In this closed gondola, Professor Piccard rose to a record altitude, 51,000 feet. However, he was not satisfied. He built a better gondola and rose still higher.

Piccard was interested in **cosmic rays** (KOZ-mik). Cosmic rays are high-speed atomic particles that come from outer space. Scientists knew that these rays might be harmful, but they did not know much about the rays themselves. How strong are cosmic rays in space? Would they be dangerous to man?

To find out about these rays, Piccard performed an experiment. He used a special photographic film to gather evi-

dence. Each particle hitting the film would make a streak on it. Piccard prepared two film packages. He left one on the ground. The other he carried into the thin air of the stratosphere. Why did Piccard leave one package on the ground?

After the flight, he compared the two film packages. The film from the stratosphere had been streaked many times. The film from the ground had few streaks. Why? Piccard hypothesized that the atmosphere blocks the cosmic rays before they reach the surface of the earth. But in space, where the air is very thin, these rays are much more numerous. In space, cosmic rays might be very dangerous to living things.

To the Edge of Space

After Piccard's flights, other balloonists flew higher and higher in closed gondolas. New experiments were performed on each flight. For example, scientists wanted to know if tiny plants and insects could live after being exposed to strong cosmic rays. To find out, a balloon carrying some plants and flies rose to 72,000 feet. The plants returned unharmed, but the insects did not survive. Before they died, however, they laid eggs. Later, these eggs hatched into normal, healthy insects.

Auguste Piccard's balloon. Where is the gondola attached to the balloon?

On this flight, too, scientists discovered that high in the stratosphere, where the cold is intense, bacteria live in the air. Bacteria are too small to be seen by the eye alone. How do you think the scientists found evidence of bacteria in the stratosphere?

Next, to learn more about cosmic rays, scientists decided to send animals on balloon flights. Four monkeys, named Eenie, Meenie, Minie, and Mo, took part in an important experiment. The monkeys were placed in a gondola designed to shield them from cosmic rays. Would the gondola block the rays? Would the monkeys be protected? To find the answer, a piece of special film was attached to each monkey.

- *Why did Piccard leave one film package on the earth?* (As a control.)

Continue by having the children read "To the Edge of Space," pages 269 and 270. Review the section, asking why plants, but not insects, survived the cosmic rays. If necessary, explain, "The cosmic rays were like thousands and thousands of very tiny bullets, which hit and shattered the atoms of the insects and plants. Insects are far more complicated than plants. When some vital parts had been damaged by the rays, they died. The less complicated plants lived, although they were hit just as often by the cosmic rays."

Scientists found evidence of bacteria in the stratosphere by sending up agar plates. The bacteria that came in contact with the plates were brought to earth, cultured, and examined.

Conclude by asking:

- *What happened to the monkeys?*
- *What would have happened to a man?*

Follow-Up: Do we still use balloons today to explore and investigate space? Have the children look into the use of balloons in infrared, radio, and solar astronomy.

The balloon rose to a height of 121,000 feet. The monkeys remained aloft for 29 hours. Finally, the gondola returned to earth by parachute. When the film was inspected, few streaks were found. The shield had protected the monkeys. For a long time, the monkeys were carefully observed. They remained healthy and were given a good home in a zoo.

With balloons, scientists were able to explore far into the unknown skies. They spent many long, difficult hours making observations and keeping records in their floating laboratories high above the earth. Bit by bit they gathered important information about temperatures, cosmic rays, and other conditions in space. Science was no longer earthbound. The pathway to space was open.

Using What You Have Learned

1. Make a chart showing famous balloon flights and the altitudes reached.

2. Visit a weather station that launches weather balloons. Watch a balloon being launched. Find out how the balloon sends back information about conditions in the air.

3. Watch for an Echo balloon in orbit. Write to the National Aeronautics and Space Administration, Washington, D.C., 20546, for information about when it can be seen. You may also find a schedule in your local newspaper. Keep a record of the times you see it.

4. Modern balloons do not use hydrogen gas for high-altitude exploration. Their gas bags are made of a special material. Find out about modern balloons in an encyclopedia.

5. Read the Jules Verne novel, *Around the World in Eighty Days*. It tells of an imaginary balloon trip made long ago.

ADDITIONAL ACTIVITIES:

Balloons, despite efforts of men like Piccard, still have stability problems. Can we stabilize a balloon at a certain altitude and keep it there? Let's experiment:

We will need to fill several very large balloons with hydrogen (dangerous, and less desirable) or helium (an inert gas, and better to use). These gases are readily available at welding and machine shops, and the people there will gladly fill a few balloons; or tanks can be purchased from chemical supply houses. Tie the balloons with knots that can be easily and repeatedly opened.

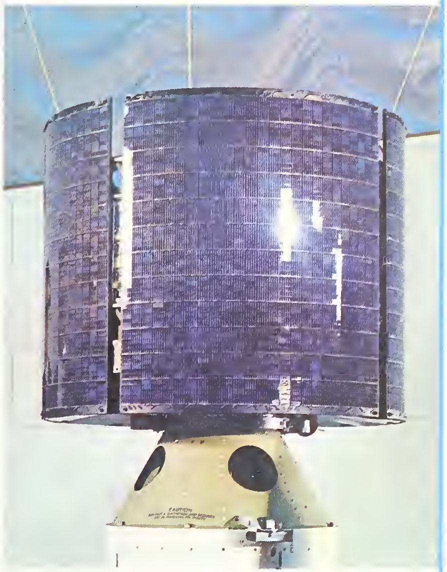
To long strings, attached to the balloons, fix weights as ballast so that the balloons hover at various heights in the classroom. One balloon can be released without weight. It will soar to the ceiling. See how long it will remain there.

After some of the balloons are stabilized (be sure to have several at convenient heights), release some gas from one balloon, warm another with gentle heat, heat the air in the vicinity of another balloon, and expose a tray of ice cubes near yet another balloon. The stability of the balloons will be affected variously by these measures, according to the properties of gases.

Rockets Explore Space

Today we live in the Space Age. **Rockets** (ROK-its) lift men into outer space. Rockets also carry small spacecraft in their noses. When a rocket reaches the top of its flight, it may fire the spacecraft into orbit. An orbit is a path around a body. When a spacecraft goes into orbit, the spacecraft is called a **satellite** (SAT-uh-lyt). Today many satellites are orbiting the earth. Spacecraft have been sent to the moon and have probed areas millions of miles from the earth, where no man has traveled. Rocket power has freed men from the powerful pull of gravity that kept them from exploring space.

Rockets such as those on the left carry satellites like the one on the right into space. Satellites are attached to the nose sections of rockets and are fired into space at great speeds by the rockets. The satellite you see below is the *Early Bird* satellite. What can you find out about this satellite?



TEACHING SUGGESTIONS
(pp. 271–278)

● **LESSON:** How do rockets work?

Background: Balloons cannot ascend into space, since they rely on the atmosphere for their buoyancy. Airplanes have this same limitation. Therefore, a new means of travel had to be invented to lift men into space. This new means is the rocket, which works on principles independent of the displacement of air.

Learnings to Be Developed:

Rockets lift satellites and men into space.

Their action is governed by Newton's Third Law of Motion: for every action there is an equal and opposite reaction.

Developing the Lesson: Have the children read the introductory paragraphs on page 271.

- *What is a rocket?*
- *How is a rocket different from a balloon?* (A rocket can fly above the air.)
- *How is it different from an airplane?* (It can fly higher and faster. It does not need air.)

When you have elicited the definition of a rocket as a flying machine that can go very swiftly and

rise above the atmosphere, ask them to define "satellite."

But why is it that a rocket can rise above the air while a balloon and an airplane cannot?

Have them read "Rocket Engines," pages 272 and 274. You may wish to perform the experiment on page 273.

Background: The experiment on page 273 is designed to prove Newton's Third Law of Motion and to provide some data about it. The balloon is launched along a thread strung between two chairs; its fuel is air.

A crude control over the air pressure within the balloon can be maintained by counting the number of uniform breaths required to fill it. Vary the number of breaths for different trials. This will give varying thrust, and the balloon will travel different distances along the thread.

You will observe that doubling the thrust will probably not double the balloon's distance. Friction between the clips and the nylon thread, the inefficient (and constantly changing) shape of the balloon, and air currents in the room will pollute the final results.

Developing the Lesson: Review carefully the material of this section, especially Newton's Third Law of

What do you feel with the hand on top of the balloon when the air rushes out? What happens when you throw a basketball forward while wearing roller skates?

Rocket Engines

How does a rocket engine work? The idea is very simple. You can find out for yourself.

Blow up a balloon. Rest the top against your hand as the air rushes out. You know the air is rushing out of the balloon because the balloon becomes smaller. Do you feel the balloon pushing back against your hand? As the air rushes out from the open end, you can feel the balloon pushing upward.

Try this when you go roller skating. While standing on your skates, throw a basketball forward. Of course, be careful where you throw it. What happens? As you throw the ball forward, you roll backward. Why? You know force is needed to move an object. When you apply a force to the ball, you set it in motion. A force also pushes on your body. You move—in the opposite direction.

Why do you roll backward? About 1680, the great English scientist Isaac Newton discovered that for every force in one direction there is an equal force in the opposite direction. This is known as Newton's **Third Law of Motion.** Perhaps you have heard it said this way: *For every action (force) there is an equal reaction (opposite force).*

Try the following experiment to find out more about Newton's Third Law.

EXPERIMENT

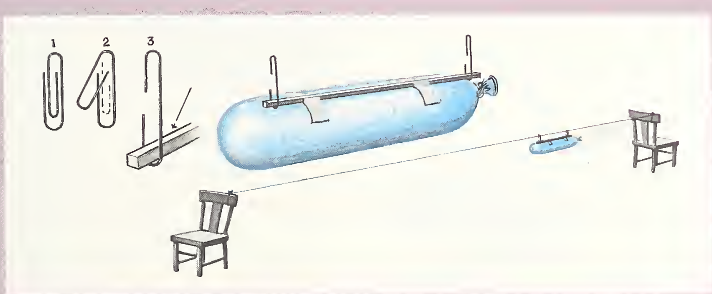
Is There an Equal and Opposite Force for Every Force?

What You Will Need

- masking tape
- long balloons
- wire
- paper clips
- balsa stick (¼-inch square and 12 inches long)
- 25 feet of nylon sewing thread
- 2 chairs

How You Can Find Out

1. Stretch the thread tightly between the chairs.
2. Make two hooks out of paper clips as shown in the diagram. Mount the hooks at each end of the stick.
3. Blow up one balloon and hold the end tightly so no air leaks out.
4. Tape the balloon to the stick as shown.
5. Carefully slip the hooks over the thread.
6. Let the balloon go and release the air from it without shaking the stick or thread.



Questions to Think About

1. Measure the distance the stick traveled. What was it?
2. Does it travel the same distance a second time?
3. Keep a record of your experiments with two balloons. What does your record show?

Motion, which is fundamental to an understanding of rocket flight.

- *How does Newton's Third Law of Motion explain what happened when you let the air out of the balloon?*
- *How does it account for what happened when the basketball was thrown forward?*

Elicit that in each case an action—the air rushing downward, the basketball being thrown forward—caused an opposite reaction: forward pressure on the hand and backward movement by the boy.

Then have the children point out the actions and reactions in the pictures on page 274. The flying platform (picture 1) has a propellor in its base that drives air downward and so drives the platform up. The sprinkler shoots water in a counterclockwise direction, causing the sprinkler to move clockwise. The rocket forces hot gases downward through its exhaust nozzles and so moves upward.

Conclude the discussion by reviewing the parts of the rocket engine: the firing chamber, in which fuel is burned to produce hot gases; and the exhaust nozzle, through which the hot gases escape and by reaction propel the rocket.

Tell the class that "rockets can carry men and satellites into space. But to do this they must travel not 25 feet, as in our experiment, but hundreds and thousand of miles. They need a great deal of power." How do they get it? Have the class read the next section, "More Power for Rockets."

Ask them to answer the question at the top of page 276. The force needed to lift 200,000 pounds is 200,000 times 1.5, or 300,000 pounds of force.

Have the children read the section "Thrust," and then ask them:

What is thrust? (The force of the rocket engine.)

What are the two ways in which we can increase thrust?

Have them reread the first paragraph on page 278 and relate what is said both to their answers and to the experiments on pages 277 and 278.

Background: The experiment on page 275 is designed to show that gravity is a force. The weight of an object is actually a measure of the force with which it is being pulled by gravity toward the center of the earth.

The brick required force greater than its weight because of its in-

Use Newton's Third Law of Motion to explain what is happening in each picture.

The air pushing out of the neck of the balloon produced a force. The stick was pushed a specific distance by an opposite force. This force was the **reaction.** Can you think of a simple way to double this force? Can you predict how far the stick will travel when the force is doubled? Design an activity to test your ideas. You can make accurate comparisons if you make careful distance measurements.

From these experiments you can see that when more balloons are added, the stick will travel a greater distance.

Newton's Third Law helps to explain how rocket engines work. Their operation depends on the **action-reaction** principle.

Rocket engines have two main parts. Fuels burn in the **firing chamber.** The hot gases produced by the fuels rush out the **exhaust nozzle.** These gases have great force. When the rocket is on the launching pad, as in the picture on page 276, the gases push downward. What happens to the rocket?

More Power for Rockets

Rockets need powerful engines. Without this power, rockets would never leave the earth. They would be held on the ground by the force of gravity.

You can measure the pull of gravity by measuring the weight of an object. You can also learn about the force needed to overcome this downward pull. To move objects away from the earth, an upward force is needed. How much?

Rockets that carry men into space are very heavy. At launching time, manned

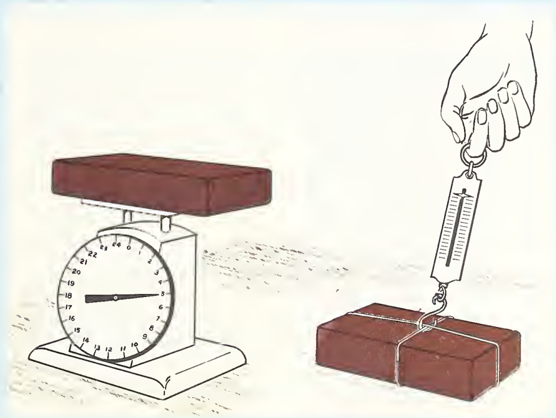
How Much Upward Force Is Needed to Move Objects Away from the Earth?

What You Will Need

kitchen scale	spring scale
brick	string

How You Can Find Out

1. Weigh the brick on the kitchen scale. It will probably weigh about 5 pounds.
2. Tie a string around the brick so that it will not slip off.
3. Attach the spring scale to the string. Watch the pointer.
4. Lift the scale slowly and smoothly until the brick is off the floor.



Questions to Think About

1. How much pull was shown on the spring scale?
2. You probably expected to see a pull of about 5 pounds. Instead, you needed somewhat more than a 5-pound pull. What does this show?

ertia, or tendency to remain at rest. (See Newton's First Law of Motion, page 280.) When this inertia was overcome, the brick rose into the air. According to the second half of Newton's First Law, the brick should continue to rise indefinitely. It doesn't, because it is acted upon by the outside forces of gravity and the friction of the air.

The answers to the *Questions to Think About* on page 275 are:

1. The amount of pull will, of course, depend on the dead weight of the brick. Whatever the dead weight, the spring scale will indicate a somewhat higher reading, which will depend on the swiftness with which the brick is pulled upward. The greater the initial jerk, the greater will be the reading on the spring scale.

2. The higher reading is caused by the inertia of the brick. It takes a larger force to overcome the inertia (i.e., to get the brick moving) than it does to maintain the upward motion of the brick once the brick is in motion.

The answers to *Questions to Think About* on page 277 are:

2. As the air rushes out of the ballon, an equal force (thrust) arises, pushing the car in the opposite direction.

3. The amount of air, and hence the amount of force, is greater. The car will move more quickly.

The answers to the *Questions to Think About* on page 278 are:

1. When you place your finger over the hose opening, the slowly moving stream of water moves faster and faster and finally squirts out with great force.

2. This happens because the area through which the water must pass is smaller than it is when your finger is not restricting the hose opening. Since the quantity of water flowing through the hose is the same, the same volume of water must pass by the restricted opening during the same period of time as when the hose is not blocked. The only way that the water can do this is by moving faster past the restricted opening. This is why the water squirts out —it is moving faster as it emerges from the end of the hose.

ADDITIONAL ACTIVITIES:

Thrust is a function of both the volume of gas escaping from the rocket and the speed with which it escapes. We can experiment with the speed at which the gas escapes by altering the size of the opening or nozzle of the vehicle.

The experiment on page 277 can be altered as follows: Secure a block of plastic foam or balsa wood, carve a small hole through it, and attach it firmly to the back piece of the vehicle in the draw-

As the amount of exhaust gas or its speed through the exhaust nozzle becomes greater, the thrust of the rocket will increase.

rockets may weigh more than 200,000 pounds. A great force is necessary to lift such mighty loads. Scientists have learned that the force should be at least one and one-half times the weight of the rocket. Can you figure the force?

Thrust

The force of a rocket engine is called the **thrust.** To increase the power of a rocket engine, more thrust must be provided. Scientists know two ways in which to do this. The experiment on the next page will help you learn one way to increase thrust. Stop and do the experiment now. Your experiment will show you that two balloons deliver more thrust than one. A greater amount of air is forced out of the balloons. The reaction, too, has greater force.

If the first launching was successful, the car was pushed along the floor. As long as the air was being forced out of the neck of the balloon, an opposite force kept pushing the car.

The car can be made to go farther and faster. To do this, you will need more thrust. You can use the same balloon. Would the thrust be different if you changed the size of the hole? Design an experiment to test your ideas. Take careful measurements of the distances traveled so that you can make

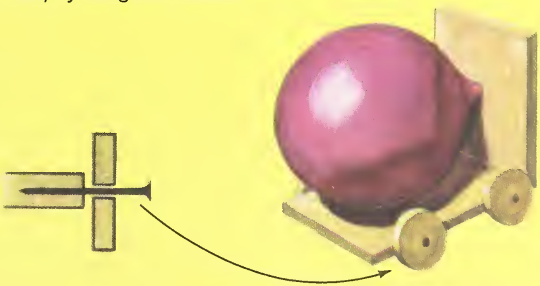
How Can Thrust Be Increased?

What You Will Need

2 balloons	2 pieces of balsa wood	pins
4 small wheels	(¼ by 2 by 3 inches for the back, and ¼ by 2 by 4 inches for the base)	4 nails
		string (18 inches)

How You Can Find Out

1. Mount the wheels on the base as shown. They should turn easily.
2. Drill a small hole (about ⅜ of an inch) in the back piece.
3. Pull the neck of one balloon through the hole.
4. Pin the back on the base.
5. Tie the ends of the string together, and put it around the middle of the balloon.
6. Blow up the balloon until it just fits the string.
7. Pinch the end of the balloon with your fingers, and make sure no air escapes. Remove the string.
8. Place the car on the floor carefully, and let the balloon go.
9. Next, try using two balloons.



Questions to Think About

1. What was the distance the car traveled? Repeat the activity, and record the results of each test.
2. What made the car move?
3. What happens when you use two balloons?

ing. Align the hole and the neck of the balloon so that the escaping air will leave through the hole in the block. By altering the size and shape (by attaching a funnel, first facing the balloon and then turned the other way), and by measuring the distance traveled during each test, the effect on the thrust of the shape of the nozzle can be determined.

Another way of measuring thrust would be to determine the time taken by the vehicle over a standard distance.

Another experiment, perhaps simpler, would be to use a cigar box or shoe box as the vehicle and a boxful of straws laid down parallel to each other as a rolling runway. Into one end of the box cut a hole as the opening for a balloon neck, and fix a variable nozzle as described above. An inflated balloon would provide the propulsion force.

Variations using string of various lengths in the experiment on page 277 may prove interesting to children with a mathematical bent. It is possible to calculate roughly the volume of air in any given balloon, and thus have a crude measurement of the "fuel" and thrust. In the original experiment, an 18-inch string was used. The string was, in effect, the circumference of the balloon. To find

the diameter of the balloon, apply the familiar formula for the circumference of the circle:

$$C = D \text{ (diameter)} \times \pi$$

$$18 = D \times 3.14$$

$$D = \frac{18}{3.14}$$

$$D = 5.732 \text{ inches}$$

The radius of the balloon was 2.88 inches.

Now, *assume* that the balloon formed a sphere, and calculate the volume of the sphere using the formula

$$\text{volume} = \frac{4 \pi r^3}{3}$$

(The value of $\frac{4}{3}\pi$ is 4.155)

The formula becomes:

$$\text{volume} = 4.155(2.88)^3$$

The volume of the balloon with a circumference of 18″ is 99.25 cubic inches.

When you set up your experiment worksheet, add a column for *Volume of Air,* perform the above calculations, and enter the volumes caused by using different lengths of string. It will become obvious that as the length of string increases (and the radius of the sphere increases) the thrust increases.

comparisons. Did the size of the hole make a difference?

Thrust depends on two things—the amount of a substance that passes out of the exhaust nozzle, and the speed at which the substance is traveling. Thrust increases as the amount or speed of exhaust through the nozzle increases.

To gain thrust, rocket engines use special fuels. When these fuels burn in the firing chamber, expanding gases blast out of the nozzle. The greater the number of gas molecules leaving the engine and the greater the speed, the greater the thrust. Some fuels have been developed that release greater amounts of energy than fuels now being used in rockets. You can change the thrust of your balloon rocket by using more or less air. Design an experiment to test the effect of using strings of various lengths.

Thrust can be increased in another way. One part of the exhaust nozzle is made with a smaller opening. When the hot gases rush past this narrow opening, their speed is increased. You can see this by doing the experiment below.

You know that the pull of gravity must be overcome when rockets blast off for space. As rockets become heavier, more thrust is needed. Engineers have learned how to increase thrust by using high-energy fuels and special exhaust nozzles. Engineers now have the powerful rockets to explore space.

EXPERIMENT

How Does a Narrow Opening Affect Thrust?

What You Will Need

garden hose attached to water source

How You Can Find Out

1. Remove nozzle from the hose.
2. Turn on the water and notice how it comes out slowly.
3. Place your finger on the opening of the hose to make it smaller.

Questions to Think About

1. What happens to the stream of water when you place your finger on the hose opening?
2. Can you tell why this happens?

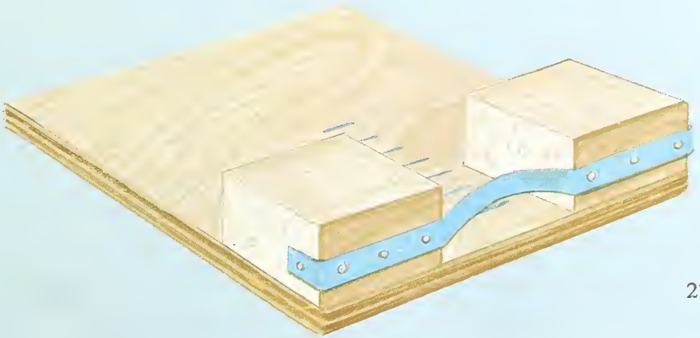
How Is an Object Placed in Orbit?

What You Will Need

plywood (¾ inches by 1 foot square) for base	nails
2 corner blocks (2 by 4 by 4 inches long)	glue
rubber strip (1 by 15 inches) cut from an old tire tube	marbles

How You Can Find Out

1. Spread glue under the corner blocks and nail them into place. Allow several hours for the glue to dry.
2. Place the rubber strip in position. Fold one end, and nail it to a corner block.
3. Nail the other end in position in the same way. When nailed, the rubber strip should be slightly loose.
4. Mark a scale in inches on the center of the base. Mark your measurements from the end of the board.
5. Place the base at the edge of a flat table top.
6. Place a marble in the center of the sling.
7. Hold the base down so that it does not slip.
8. Pull the marble in the sling back to the 2-inch mark.
9. Let the marble go when no one is in the way.
10. See the picture below and then turn to page 280 for the rest of this experiment.



(pp. 279–283)

LESSON: How do rockets get into orbit?

Learnings to Be Developed:

The path of a rocket through the air is like the path of any launched object.

The orbit of a satellite is a path whose curve is the same as the earth's curve.

To attain the speed necessary to orbit, multistage rockets are used.

Developing the Lesson: Have the children read the selection "Going into Orbit," on page 280. Review carefully the concepts of this section.

What is Newton's First Law of Motion?

Can you think of any examples of it?

Pupils should have no trouble thinking of objects that remain at rest.

But what about an object continuing in a straight line when in motion? Did the marble do that? Why not?

Reread the law, emphasizing the last phrase, "unless an outside force works on it."

- *What outside force was working on our marble?* (Gravity.)
- *What direction was it pulling the marble?* (Downward.)

The illustration at the bottom left of page 281 shows a marble resting on a table. The colored arrows represent the forces acting on the marble. The red arrow represents the push given the marble to start it moving in a horizontal direction. The blue arrow pointing downward represents the force of gravity acting upon the marble as it rests on the table. The blue arrow pointing upward represents the upward reaction of the table against the force of gravity. If this force weren't present, there would be nothing to prevent the ball from breaking through the table under the force of gravity. (Although one never thinks about it, this reacting force is always present in material substances. It is the strength—a resistance to outside forces—within a substance that enables it to bear the stresses and strains placed upon it.)

The illustration at the bottom right shows what happens when the ball falls off the end of the table. In effect, the upward-pointing arrow has been removed.

Continue: "If Newton's First Law helps us see what path the marble

Questions to Think About

1. How far does the marble travel horizontally before it reaches the ground? Measure this from a point directly below the edge of the table. Try this several times, and keep a record of the results.
2. Compare the results. Are they the same?
3. If the results are not the same, can you explain why?

Going into Orbit

"Everything that goes up must come down." In the past, people did not question this statement. Today, we know that it is not true. Just a few years ago, scientists placed many types of spacecraft into orbit around the earth. After a while most of the spacecraft came down, but there are still some orbiting the earth. How would you go about finding out which satellites they are? How long are they expected to stay in orbit?

In the experiment, you found that each time you shot the marble with the rubber sling, the marble started off in a horizontal direction. Over two hundred years ago Isaac Newton studied motion. The result of his studies was his **Laws of Motion.** According to Newton's **First Law of Motion,** the marble should have continued to move at the same speed and in the same direction. Newton's First Law states that *an object at rest remains at rest, or if in motion continues in motion in a straight line and at the same speed, unless an outside force acts on it.* But you saw that the marble changed its direction. It moved in a curved path toward the earth!

The marble moves in two directions. One direction is *horizontal*, or straight out in line with the ground. Once the marble starts to move, no other horizontal force acts on it. Its horizontal rate of speed remains the same. The other direction of the marble is *vertical*, or down. The force of gravity is a *constant* force that keeps pulling the marble down, making it fall faster and faster. This is explained by Newton's **Second Law of Motion,** which says that *the rate at which the speed of an object changes depends on two things: the mass of the object and the force applied to it.* For example, if you push a wagon hard enough it will start to move, and if you apply a constant force, the wagon

will go faster and faster until the friction of the wheels and the resistance of the air act as opposing forces. In the same way as your pushing the wagon, the force of gravity on the marble makes the marble speed up as it falls.

The horizontal and vertical forces on the marble combined to make the marble move in a curved path.

Can you change the shape of the marble's path? When the sling was stretched to the 2-inch mark, the marble traveled a certain horizontal distance. You measured that distance. Can you predict how far it will travel if the sling is stretched twice as far—to the 4-inch mark? How far with the sling stretched to 6 inches?

Enter your *predicted data* on a graph.

Now test your ideas by experimenting. Make careful measurements. Enter the *experimental data* on the graph. How do your predictions compare with the evidence? If they are not the same, can you explain the differences?

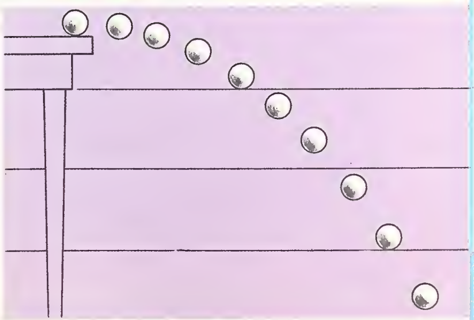
In your experiments, the vertical force on the marble remains the same. The force of gravity makes the marble fall at an increasing rate. It always takes a certain time to reach the floor. For example, suppose the table top is 30 inches high. From that height, the marble will reach the floor in about $\frac{2}{5}$ second. Will this happen each time, no matter how great the horizontal speed?

The horizontal force on the marble changes when you pull back farther on the slingshot. When the force is increased, the horizontal speed of the marble increases. The greater the horizontal speed, the farther the marble will travel before reaching the floor.

Does this look something like a picture of the path that the marble took as it was shot by the slingshot?

In what directions does the marble move? What force acts to pull the marble down?

The picture below shows the path the marble took when shot by the slingshot.



will take, his Second Law will help us see how quickly it will go through that path."

- *What is the Second Law?*

When they state the law, continue: "Gravity speeds the marble down through its path."

- *What was the horizontal force that acted on the marble?*
- *What was the vertical force?*

The marble will always hit the floor in $^2/_5$ of a second when shot from a 30″ table. This is true whether it leaves the slingshot at 1 mile/month or 1 mile/second. Refer to the picture, right-hand side, at the bottom of page 281. Gravity, the vertical force acting upon the marble, works only to drag the marble down through 30″ to the floor. The slingshot, on the other hand, works only to lengthen the marble's horizontal path. Thus, by increasing the slingshot's force, you do not work against gravity's action. Increasing the force of the slingshot makes the marble's horizontal path longer, but it still falls through only 30″ and so hits the floor in $^2/_5$ second.

Each time the rocket is shot faster, it curves further around the earth before gravity brings it to the ground. At 5 miles per second, it goes all the way around the earth,

back through its starting point, and around again, and again.

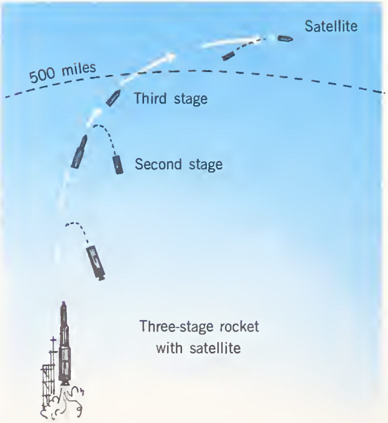
Have the children read the section "Multistage Rockets." Refer to the diagram on page 282 and ask the children to summarize what they have read.

- *What does the first stage do?* (It lifts the entire weight of the rocket and its load of instruments, fuel, and spacecraft from the earth. When its fuel is gone, the first stage falls away.)
- *What does the second stage do?* (It increases the speed of the rocket still further. When its fuel is gone, it also falls away.)
- *What does the third stage do?* (It accelerates the rocket to its final speed. Then it, too, falls away, leaving the spacecraft and its instruments in the final orbit.)
- *Which stage is the heaviest? Why?* (The first stage is the heaviest, because it carries the largest amount of fuel and must be strong enough to carry the entire weight of the rocket while it is on the ground.)
- *Which stage is the lightest? Why?* (The third stage is the lightest, since it need carry only enough fuel to place the spacecraft in its final orbit.)

What would happen if you could shoot a marble horizontally at a speed of 3 miles a second? Imagine that you are experimenting from a tall tower. Suppose there is nothing in the way and no air friction to slow down the marble. At this speed, the marble would travel horizontally for a great distance, but its path would still be a curve. In a short time, it would strike the ground.

Suppose you were to launch a satellite with a horizontal speed of 5 miles a second. It, too, would travel toward the earth in a curved path. But the earth is also curved, and the pull of gravity is always toward the earth's center. Every 5 miles, the earth curves downward just as much as the satellite would fall downward. The satellite would continue around the earth in a circular path. It would be in orbit, circling the earth every 84 minutes. If there were nothing in the way and no air friction, the satellite would remain in orbit.

Explain why a satellite launched with a horizontal speed of 5 miles a second orbits the earth.



Multistage Rockets

Horizontal speeds of at least 5 miles a second, or 18,000 miles an hour, are needed to place spacecraft in orbit. To reach this speed, scientists often use **multistage rockets.** *Multi* means "many."

A multistage rocket is made up of two or more rockets. The first stage, or first rocket, has the greatest thrust. It boosts the entire load of fuel, instruments, and spacecraft for the first 20 or 30 miles. It also guides the rocket toward a horizontal flight path. When the fuel is burned up, this stage is no longer needed; it can do no more work and is dead weight. The stage is then dropped off.

The second stage is fired. The speed of the rocket increases, and the rocket soars still higher. When the fuel is used up in the second stage, this stage, too, is cast off. Each remaining stage gives extra speed. The rocket goes higher and faster.

The final stage is fired, and a three-stage spacecraft is now free from its stages. It travels horizontally at 5 miles a second. It will orbit the earth.

Spacecraft remain in orbit as long as their average speed is unchanged. But even 100 miles above the earth, some air is found. As the satellite pushes through this thin air, it is gradually slowed down. Gravity pulls it steadily toward the earth. It orbits lower and lower. When the spacecraft enters the upper atmosphere, the friction of air molecules makes the spacecraft very hot. However, the spacecraft can be controlled so that it will enter the atmosphere more slowly and will not burn.

Spacecraft for Special Missions

Spacecraft that orbit the earth are designed for various experiments. American spacecraft are grouped. Below and on the next page are pictures of rockets in each group.

Explorer and *Vanguard* spacecraft collect information about radiation, meteoroids, and temperatures in space. What has been learned so far from these space probes?

When a spacecraft moves at 5 miles per second, its horizontal motion combines with gravity's vertical force and it falls in a curve around the earth. The curve is its orbit.

Continue: "You know from what you have read that multistage rockets sometimes weigh 200,000 pounds and therefore need 300,000 pounds of thrust. Yet the satellites that the rockets put into orbit weigh only a few hundred pounds. Was all that rocket power necessary to put a few hundred pounds into orbit?"

Much of the rocket's power is used to lift the rocket and its fuel. Help the children see this. "If your fuel does not give much thrust, you have to burn a great deal of it to give enough speed to escape the gravity of the earth. But more fuel weighs more, so your rocket is heavier. And you need even *more* fuel to lift that fuel. And so on, and so on. It is easy to see why rockets today are so large.

- *Can you tell why scientists are searching for light, very powerful rocket fuels?*

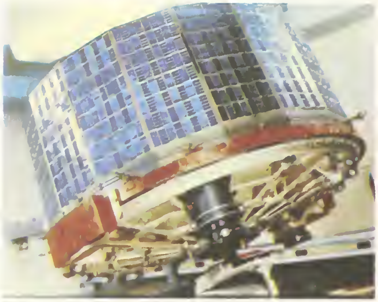
- *Can you see the advantage of multistage rockets?* (The weight of the rocket is lessened by jettisoning useless stages.)

TEACHING SUGGESTIONS
(p. 284)

Background: If there is one man who can be called the father of the space age, it is Robert H. Goddard. He was the first physicist to interest himself seriously in the problems of rocket flight, the first to use liquid oxygen as a fuel, the first to design and build combustion chambers and exhaust nozzles that could withstand the heat and pressures developed within the engine, the first to build gyroscopic control systems that guided the flight of the rockets, and the first to design and build multistage rockets.

Goddard obtained a small grant from the Smithsonian Institute to continue his experiments. With it he built a second rocket, as described in the text. As a consequence of the noise and fire associated with this flight, he was forbidden to fly any more rockets in the state of Massachusetts.

During World War II his talents were used to develop the bazooka, a rocket-propelled projectile, but no use was made of his knowledge of high-flying, long-range rockets. German scientists, using the knowledge gained by Goddard, built the first large, practical rocket—the V-2 that bombed London.



Tiros spacecraft carry television cameras to take pictures of clouds.

Ranger spacecraft's television cameras send pictures of the moon back to earth.

Echo spacecraft reflect communications signals and supply data about solar radiation.

PATHFINDERS IN SCIENCE

Robert H. Goddard

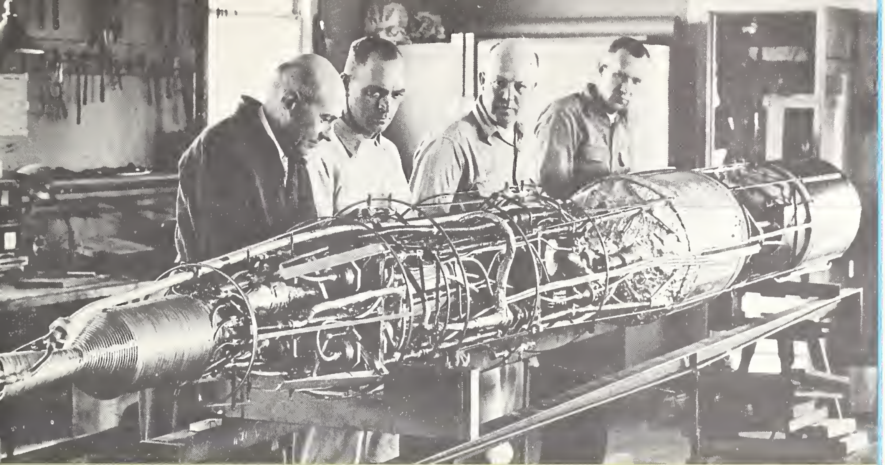
(1882–1945) United States

Some people are able to think far ahead of their own time. They have new ideas and think of new and better ways to do things. But other people are not always able to understand these new ideas. Robert Goddard's ideas were far ahead of his time.

Robert Goddard always dreamed of exploring the skies. As a college student, he decided that rockets would be the best way to travel into outer space. He studied rockets to figure out how they could work better and fly higher. He tested rockets in the basement of a college building. Students laughed at him, and teachers called him a daydreamer. Most people thought rockets were used only to celebrate holidays and to carry signals into the air from the decks of ships. The idea that a rocket could be made powerful enough to go far into the sky seemed silly.

After graduation from college, Dr. Goddard became a teacher at a university, but he continued his research into rockets. More and more people began to believe in his work and offered to help him.

On March 16, 1926, Dr. Goddard tested one of his rockets. He set up the launching frame and placed a four-foot rocket in



Robert Goddard, on the left, is shown assembling one of his rockets.

it. A flaming torch, called a blowtorch, was touched to the combustion chamber. Dr. Goddard pulled a cord. The rocket roared and flamed. It began to rise slowly and then, with increasing speed, jumped into the air. The test flight was a success! The first liquid-fuel rocket had been launched. It traveled 60 miles an hour and went 200 feet into the air.

Three years later, Dr. Goddard launched a rocket that soared twice as high as the first one. But many people who read the newspaper reports did not think of the professor as a real scientist. They thought of him as a man who played with rockets, the way children play with firecrackers.

Dr. Goddard was discouraged and did not have much money left for his tests. But Charles A. Lindbergh, the first pilot to fly a plane alone across the Atlantic Ocean, was convinced of the importance of Dr. Goddard's work. With his help, Dr. Goddard was able to give up teaching and spend all his time on rocket research.

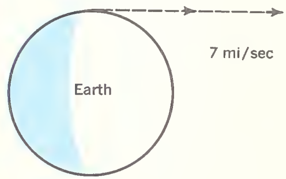
Dr. Goddard was the first to see the importance of placing instruments in his rockets. One of his first rockets carried a barometer, a thermometer, and, most important, a camera to record the readings on these instruments. By 1935, Dr. Goddard's rockets reached heights of over a mile and traveled 550 miles an hour.

Today, rockets soar far into space. Dr. Goddard's faith in himself and his ideas made possible today's exciting probes into outer space.

TEACHING SUGGESTIONS
(pp. 285–288)

Learnings to Be Developed: Space probes are instrument-bearing spacecraft that gather and send information about parts of the solar system.

Developing the Lesson: Have the children read the section titled "Space Probes." Refer to the diagrams made for page 282 to explain escape speed. Then discuss the diagram below:



- *What deep space probes are in space now?*
- *Where are they going?*
- *What are they designed to do?*

Background: Answers to *Using What You Have Learned* are:

1. If the marble is launched at an angle from the horizontal, its path will be different from that when the marble is launched horizontally. The major difference that can be observed is that the marble travels a greater distance when the launcher is tilted upward. In general, if the marble is always launched with the same force, it will travel farther the greater the angle is from the horizontal, up to an angle of 45°. At angles greater than 45° the marble will not travel so far. At an angle of 90° it will, of course, simply travel straight up and down.

How this would affect a satellite's orbit depends on what happens to it at the top of its trajectory. If, at the top of its trajectory, it is given a boost in a horizontal direction, it will then travel farther than if it were launched horizontally in the first place.

2. The marbles should take the same amount of time to roll down the track, since the gravitational pull on both of them will be the same. How they act after they have reached the bottom of the track and roll down the smooth, level floor is a different question. The heavier ball has the greater

Space Probes

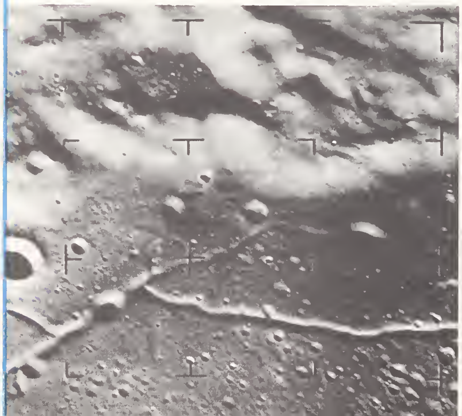
Spacecraft that explore into space are called **space probes.** To launch a space probe, powerful engines boost its horizontal speed to about 7 miles a second. This is the **escape speed** from the earth. At this speed, spacecraft escape from the earth. The earth's gravity slows the probe, but the probe never falls back to earth. Instead, it enters a region in space where the gravity of other objects in the solar system is stronger than the earth's gravity. Then the probe may go into a new orbit and circle the moon, the sun, or another planet.

The United States and Russia have launched **deep space probes.** Some of these probes have explored the moon. Evidence gathered by them shows that the moon has no air and probably does not have a magnetic field like the earth has.

Some probes have been launched far into space. They will never return to earth. Instead, they will go into orbit around the sun. There, they will become new, man-made members of the solar system.

The instruments carried in spacecraft have brought men new knowledge about the earth and space beyond it. Exploring with spacecraft is a great dream come true. It has also prepared men for the greatest adventure of all time—space travel.

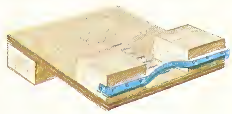
Ranger IX spacecraft took a photograph of the moon on March 24, 1965, from 115 miles away.



In July 1965 the first close-up photographs of Mars were taken by the *Mariner IV* satellite.

Using What You have Learned

1. You have learned about paths taken by an object that is launched *horizontally*. Are the paths the same if the object is launched at an *angle?* Set up your rubber sling apparatus as shown in the sketch. Repeat the experiment on page 279. Take new measurements of the horizontal distances. Compare them with the measurements taken when the board is flat. Are the distances the same? How would this affect a satellite's orbit?



Put the block at various positions to get different angles of launch.

2. Which will travel faster down a track, a light marble or a heavy marble? To find out, do this experiment on a long, smooth, level floor. Set up a piece of angle iron or aluminum track. Weigh the marbles. Then place them on the track and let them go. Which marble traveled faster? Did you find the answer you expected? Can you explain what you found out? Compare the distances each one traveled. Did the marbles travel the same distance? Why?

3. Look at the chart showing escape speeds from some bodies in the solar system. Can you explain why the escape speeds from these bodies are not the same?

Escape Speed

Planet	Miles per Second
MERCURY	2.5
MARS	3.2
VENUS	6.4
EARTH	7.0
JUPITER	37.5

mass and, therefore, the greater amount of inertia. It will roll more slowly but travel farther. The lighter ball will roll faster but it won't travel as far.

The greater the disparity between the two balls, the more evident this will become. Rolling a marble and a bowling ball down a ramp, for example, will show the differences clearly, but the time it takes to roll both the length of the angle-iron track will still be so close that it is doubtful that your pupils will notice any difference in time.

3. The smaller the planet, the less massive it is; the less massive, the less gravity it exerts. The less gravity it exerts, the less force is needed to escape it; hence the lower escape speed.

5. The 5 miles/second speed of the rocket plus the additional 2 miles/second speed adds up to 7 miles/second. This is escape speed for the earth. The rocket would depart into interplanetary space.

6. There would be no horizontal motion and the rocket would fall.

ADDITIONAL ACTIVITIES:

Swing a ball on a string in a nice wide circle and then let it go.

- *What forces are acting on the ball?* (Inertial force of motion and the pull of the string.)
- *If each force acted independently, what would be the result?* (The inertia would cause the ball to continue on in a straight line. This can be diagrammed as a tangent to the circle of the actual path of the ball while the string is held in the hand. The string would cause the ball to be pulled to the hand holding the string.)
- *What is this experiment like? To what is it analogous?* (Satellite in orbit, moon swinging around the earth, etc. The motion of the ball is analogous to rocket propulsion; the pull of the string is analogous to the pull of gravity.)

Swing a paper clip in an arc on the end of a string, or swing it in a circle. Keeping the paper clip in constant motion, bring a bar magnet slowly toward the clip until there is an obvious effect on the swing. Now speed up the swing of the paper clip. The attractive effect of the magnet is reduced by the added speed.

4. Use an encyclopedia to find out about experiments performed by the following spacecraft groups: *Pioneer, Transit,* and *Telstar*.

5. Suppose you are in a spacecraft moving in orbit at 5 miles a second. You shoot a rocket in the same direction in which you are moving. It speeds away from you at 2 miles a second. Can you explain what will happen to the rocket?

6. Suppose the rocket is shot 2 miles a second in the direction opposite to the motion of the spacecraft. Explain what will happen to the rocket.

Men Venture into Space

One of the greatest adventures of mankind has begun. Man has orbited the earth and returned safely. Now he is able to learn firsthand about space and space travel. Let us find out how he has accomplished this.

The space pilot lies strapped in his spacecraft waiting for the take-off. Everything is ready. Seconds later the powerful engines that have been warming up beneath him thunder to life. The rocket lifts off the launching pad and climbs toward the sky. Another man in another spacecraft is going into orbit.

Who are the men who ride rockets into space? In the United States they are called **astronauts.** Russian space pilots are called **cosmonauts.** You have probably seen their pictures in newspapers and magazines, and on television.

Feeling Weightless

Astronauts feel weightless when they travel in space. You experience something of this peculiar feeling of weightlessness when you swim. When you float in water, you feel almost as if you had no weight. It is a pleasant sensation, but how would you feel if there were *no* water in the pool and you still floated?

To learn more about this strange feeling, astronauts are flown in a special type of airplane. The seats are removed, and the cabins are empty. The

John Glenn was the first United States astronaut to orbit the earth. On the right, astronauts Grissom and Young get ready to make the first United States two-man flight into space. Below on the left is a Russian cosmonaut, the first man to leave a spacecraft during its flight. On the right is United States astronaut Edward White, walking in space attached to his spacecraft by a cable.

TEACHING SUGGESTIONS
(pp. 289–294)

● **LESSON:** What does man weigh in space?

Background: Gravity attempts to drag us down to the center of the earth. Weight is caused by the fact that we stand on solid ground and so resist gravity's tendency. In the environment of space, conditions are very different.

Learnings to Be Developed:

Men on a spacecraft in orbit feel no weight.

On the other hand, men within a rapidly accelerating rocket experience G forces, which make them feel as if they had many times their normal weight.

G forces can be duplicated in man-made machines, such as, rocket sleds and centrifuges.

Space stations will probably spin on their axes to provide artificial gravity.

Developing the Lesson: You may want to introduce this lesson by asking:

- *What will it be like in space?*

Have pupils read the introductory section, and then "Feeling Weightless," on pages 288 and 290. Ask:

- *Can anyone tell me why astronauts sometimes feel no weight?*

Refer to the lower pictures on page 289. The left-hand picture (whose quality is poor because it was taken from a television screen) is unique in that it is a picture of man's first walk in space.

- *Was Edward White or the Russian cosmonaut experiencing weight when these pictures were taken?* (No.)

If the children have difficulty understanding why a person feels weight, ask:

- *Why do we feel weight?*
- *Is gravity pulling us down?*
- *What happens when you stand on a bathroom scale?*

Help them see that the force of gravity pulls them down. This downward pull presses against a platform. The downward push on the platform moves the needles and indicates their weight.

"Now imagine this. Imagine that the ground beneath you suddenly disappears, and both you and the scale are falling through space just as swiftly as the pull of gravity permits. You step onto the scale."

walls and floors are covered with soft materials. High in the air, the plane goes into a steep climb. Then it noses down in a curve toward the earth. The plane and its passengers are moving under the same pull of gravity. The plane is not pushing up on its passengers, nor are the passengers pushing down on the plane. They float around the cabin, feeling weightless, for half a minute. Astronauts take many of these flights to get used to the sensation of weightlessness.

On long space flights the spaceship and everything inside will be weightless. Objects such as furniture and equipment will have to be very firmly anchored in place.

The first astronauts to circle the earth managed very well during the short time that they were weightless. What will happen on longer flights? Scientists are doing many tests to find out.

Weightlessness presents problems in eating and drinking, too. How can the astronaut keep from spilling his food? One solution has been found. Astronauts use a squeeze bottle for food. The bottle keeps the food in place. When the bottle is squeezed, food travels through the tube into the mouth. Can one swallow without the force of gravity? How can you find out?

It may be necessary to produce **artificial gravity.** The circular motion of a machine called a **centrifuge** (SEN-truh-fyooj) produces a force similar to the force of gravity. Perhaps the cabins of spaceships will be made to spin. Then a person in the cabin would feel as if he had weight.

Eating in space can be done by using plastic squeeze bottles.

G Forces

Astronauts do not always feel weightless when they fly into space. During lift-off, the rocket continually gains speed. As the rocket climbs, the astronaut is pressed into his seat with great force. His weight may be eight times the normal pull of gravity. This condition is called 8 **G's.** When he re-enters the atmosphere and his capsule slows down, his body tends to move forward with great force.

Lt. Col. Stapp rode a rocket-propelled test sled that in 5 seconds reached a speed of 421 miles per hour. Col. Stapp's body felt a force of 12 G's. The last three pictures show what happened when thrust stopped because the rockets burned out. The force on Col. Stapp was 22 G's. Why are such tests important?

You can get some idea about **G forces** in an automobile. If the car came to a sudden stop, you would be thrown forward. To keep you safe when a car stops suddenly, all cars should have seat belts to hold you in place.

What happens to an astronaut at 8 G's? His arms feel as heavy as lead, and he can hardly lift them. He may find it difficult to speak. His heart pumps faster, and breathing becomes difficult. Every part of his body seems to be eight times its normal weight.

Years ago nobody knew how these G forces would affect people. To find out more about this problem, a special sled powered by rockets was built. It ran on rails. The sled could move from a standstill to 600 miles per hour in a few seconds. It could stop just as quickly.

Models of human beings went on the first test rides. After each test, the models were carefully studied to see how the ride affected them. Later, an Air Force doctor, Colonel John P. Stapp, rode the sled. The sled roared down the rails. For a few seconds he was pressed to his seat with a force 12 times his weight. Normally, Colonel Stapp weighed about 160 pounds. On this ride, how much force was pressing Colonel Stapp backward?

- *Would your weight show?*

"No, it would not, because you would not be pressing against the scale. The scale would be falling just as fast as you. Neither of you would have any weight." If they are able to understand the analogy, continue: "The scale is the spaceship, falling around the earth, and you are inside it, feeling no weight."

- *What are the disadvantages of weightlessness?*

Have the children read the section "G Forces." This is complex material and should be reviewed carefully with the pupils.

It is possible to continue the example of the scale and falling man to give the children a visual insight into the G forces of acceleration and deceleration. Begin, "Do you remember our scale, falling freely through space? Now imagine that as you and the scale fell, the scale suddenly stopped."

- *What would happen when you hit the platform?*
- *Would the scale show weight?*
- *Would you feel weight?* (Yes.)

"Now, suppose that the scale was falling some distance below you. Then suddenly it didn't simply stop, but moved up, in the opposite direction."

* *When you landed on it, would you feel yet more weight?*
* *Would it show still more weight?* (Yes.)

"Now imagine that the scale started to rise faster and faster while you were trying to fall."

* *Would you feel even greater weight?*
* *Would even more weight be shown on the scale dial?* (Yes.)

Retrace the analogy, substituting "spaceship" for scale. This is what the spacemen feel. The rocket is like the scale. When it moves faster and faster, they are pressed against it.

You might wish to ask:

* *What would happen if our scale, after going faster and faster, stopped increasing its speed?*

Help them see that this state is the same as the weightless state of the first example.

* *What happens to people under several G's?*

Explain that one G is a force equal to the normal force of the earth's gravity.

* *We are all under 1 G of force now. How much do you weigh?*

What happened to Colonel Stapp? Although nothing hit him during the ride, he got two black eyes. How did this happen? Colonel Stapp made even faster rides in the rocket sled. From these experiments, it was learned that men are not seriously injured when subjected to **high-G forces** for short periods.

DEMONSTRATION

How Does a Centrifuge Work?

What You Will Need

small rubber ball   3 feet of string

How You Can Find Out

1. Tie one end of the string around the ball. Tie it tightly so it will not come loose.
2. Go out on the playground. Make sure no one is in the way. Hold the end of the string and start twirling the ball. Keep it moving in orbit around you at a steady speed.
3. Now swing the ball more rapidly. This will make it orbit more quickly than before.

Questions to Think About

1. What do you notice about the pull on the string?
2. How does this show you how a centrifuge works?

Each rocket-sled experiment lasted only a few seconds. But astronauts are likely to experience high G's for several minutes. Can a man learn to think clearly and do work under this force? How can scientists find out?

A special machine, the centrifuge, was built to find out. The picture shows you what it looks like. The astronaut rides in the seat at the end of the beam. The beam starts spinning with a circular motion. As the beam spins, a force presses against the astronaut. It acts just like artificial gravity. The faster the centrifuge spins, the greater the force exerted on the astronaut. The activity on page 292 will help you understand why this is so.

Newton's laws help explain the circular motions of all objects—a centrifuge, a spinning ball, a spacecraft, or the moon.

In the experiment, when you first twirled the ball into orbit around you, the string had to be pulled inward just a bit. You quickly found out how much force was needed to keep the ball in its orbit. Remember, the force you exerted was a constant force. Look at page 294.

When you apply a constant force, objects speed up. The constant force of the string makes the orbiting ball speed up. This increase in speed is in the direction

An astronaut takes a ride in a centrifuge to prepare himself for conditions he may face during his flight into space.

of your hand at the center of the circle. The ball tends to move inward, toward the center.

But another force **(AB)** acts on the ball. You gave the ball force when you started it moving at a certain speed. According to Newton's first law, the ball should continue to move in a straight line at that steady speed unless another force acts on it.

- *How much would you weigh if you were under 2 G's of force?* (Twice as much.)
- *What does "G" stand for?* (Gravity.)

Colonel Stapp under 12 G's weighed 12 times 160 pounds, or 1,920 pounds. He was pressed backwards by 1,920 pounds of force.

The acceleration and deceleration of Colonel Stapp's rocket sled ruptured the blood vessels near the surface of his skin and caused hemorrhaging.

Background: The answers to the *Questions to Think About* on page 292 are:

1. The pull on the string is greater when the ball is swung more rapidly.

2. The pull is the force tending to make the ball go on a path in the direction of the string. Imagine a man, not a ball, on the string. These forces would act on the man, and he would experience them as increased weight.

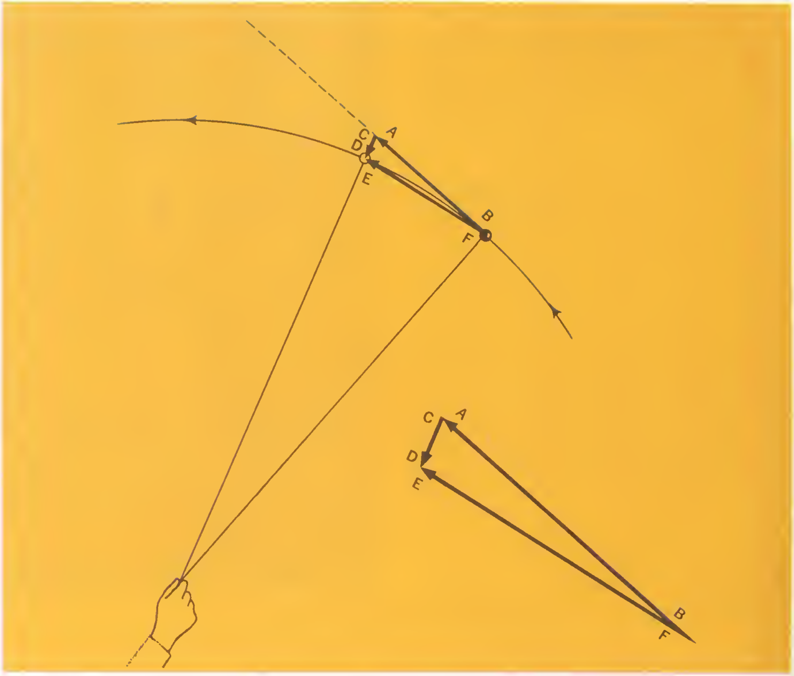
Background: The concepts underlying the centrifuge are somewhat difficult to master. If necessary, lead the children paragraph by paragraph through the explanation on pages 293 and 294. Refer to the diagram on page 294.

The diagram explains why the ball on the string takes the path that it does. The ball's path is the result of two forces: its tendency to fly off in a straight line, and its tendency to fall toward the center. The latter force is the downward pull of the string.

Refer to the diagram. If the arrow *AB* is made longer, that is, if the outward force on the ball is increased, then the tension on the string must be increased also to keep the ball in its original path. A man in the position of the ball would feel the forces as weight. The greater the force *AB*, the greater the weight he would feel.

Follow-Up: Have the children perform the experiment on page 292 with the ball and the string. When the ball is in motion, have them suddenly lengthen, then shorten, the string.

- *What happened to the ball?*
- *Why did this happen?*



Use the diagram to help explain the text below about the swinging ball.

You apply the force **CD** when you pull in on the string. When this force is applied to the ball, it "falls" toward your hand. Why does the ball continue to move in the same path **(EF)** at a steady speed? Look at the diagram. The lengths of the arrows represent the sizes of the forces acting on the ball.

Suppose the forward speed of the ball is increased. To keep the ball in the same path it traveled before, the force pulling the ball toward the center must be increased. Draw a diagram to show this. Compare the sizes of the forces in your diagram with the sizes of the forces shown for the slower motion above.

In these two examples, you learned about the forces when a ball is in circular motion. Do you now understand these forces better?

When astronauts are spinning rapidly in a centrifuge, they are acted on by a force many times the force of gravity. After a while the astronauts learn how to live, work, and solve problems while these forces continue to act upon their bodies.

Longer Space Flights

Man has journeyed into space for only short periods of time. What problems must be solved before man can go farther into space? What solutions are scientists suggesting for these problems? How can you find out?

Outer space has no air. Three hundred miles from the earth there is not enough air to keep a man alive. In fact, almost all of the earth's atmosphere is within the first 23 miles. On a trip far into space there would be air for only a few miles of the flight.

The atmosphere has pressure. It pushes upon your body. The air in your body has pressure. The air in your body pushes outward. These pressures are nearly the same. Because they almost balance each other, you do not feel either of them.

Since there is no atmosphere in space, there is no atmospheric pressure. In space there would be pressure outward from the air in the body but no pressure on the body from outside. This would be fatal. You can see why spacecraft, space stations, and space suits will have to be pressurized. Then people inside them will have almost the same pressure on them that they usually have on earth. Scientists have worked on this problem for some time. The first astronauts wore pressurized suits on their trips, and their spacecraft had pressurized cabins.

All living things need oxygen. On long space flights, travelers will need a plentiful supply. Oxygen could be placed in storage tanks before the rocket takes off. But the tanks are very heavy, and the take-off load would be great.

Another way of getting oxygen might be to pick up supplies at space stations along the way. But how could the space stations get their oxygen supply?

Scientists are experimenting with a way of producing oxygen inside the spacecraft. They are using tiny green plants called **algae** (AL-jee). The algae are placed in large water tanks, where a bright light shines on the algae. As they grow, algae use carbon dioxide and water to produce food. At the same time, they give off oxygen.

TEACHING SUGGESTIONS
(pp. 295–299)

LESSON: What must man take with him into space?

Learnings to Be Developed:

To provide men with air and carbon dioxide control in space, algae will be used.

Food will probably be irradiated or dry frozen.

Spacemen will use water many times over, purifying it again and again.

Developing the Lesson: Begin the lesson by recalling the section on balloons.

- *What did men discover when they ascended into the stratosphere in balloons?*

Establish that it was necessary for the balloonists to take along their own air.

- *If the balloon had stayed up for several days, would Dr. Piccard have been able to find food and water in the stratosphere?*

- *What will men do when they go into space for a month or longer?*

Have the class read to the bottom of the first column on page 298 to find out what scientsists are doing

about the problems of air, food, and water.

When the children have finished, review the sections one at a time.

- *How has the problem of internal body pressure been handled?*
- *How are algae being used to solve the problems of oxygen and carbon dioxide?*
- *Our book gives us two approaches to the problem of food. What are they?*
- *What are the basic nutrients that man needs?* (Water; energy foods, such as, carbohydrates and fats; and building foods, such as proteins.)
- *What are good sources of energy foods?* (Generally starchy foods, candy, butter, oils, etc.)
- *What are sources of building foods?* (Meat, eggs, milk, fish, etc.)
- *How can these foods be preserved for long periods?* (Refrigeration, freezing, dehydration, irradiation, freeze-drying, chemicals, etc.)
- *Why are most of these methods impractical for long space flights?* (They require bulky storage—refrigerators, freezers, food bins, etc.)

EXPERIMENT

How Can Oxygen Be Made by Using a Plant?

What You Will Need

elodea (from a pond, aquarium, or pet shop)
small test tube
small pan

How You Can Find Out

1. Fill the test tube with water. Put in the elodea plant.
2. Fill the pan with water almost to the top.
3. Cover the top of the test tube with your fingers or a small piece of cardboard.
4. Carefully turn the test tube over so that its mouth points down to the water.
5. Place the test tube with the plant into the water and remove your fingers. The water should remain in the test tube.
6. Make certain there is no air in the test tube.
7. Carefully place the materials under a very bright light and leave them there for thirty minutes.

Questions to Think About

1. Did you find any bubbles at the top of the test tube after the specified time? If not, do not disturb the materials. Leave them in the light for a longer time.
2. What are the bubbles you see?
3. How are these bubbles produced?

Use the diagram to show how algae may be used to supply oxygen for astronauts.

In your experiment, a small amount of oxygen was formed. In laboratories, large tanks of algae have produced enough oxygen to keep small animals alive for a long time. This way of producing oxygen may solve the problem of providing oxygen on long space flights.

Let us suppose that the oxygen problem can be solved. Another problem must be solved at the same time. You exhale carbon dioxide, gas that is harmless in small amounts. But in a spaceship, the carbon dioxide in the air will increase. How will the carbon dioxide be removed from the air?

As they grow, algae need carbon dioxide. Since carbon dioxide is exhaled by the space travelers, the algae can take in the carbon dioxide that would be harmful and, at the same time, give off oxygen needed by the passengers.

Carbon dioxide may also be removed with several chemicals. The carbon dioxide combines with the chemical substance. It is no longer carbon dioxide. It is part of a chemical compound. Spaceships would have to carry large amounts of chemicals to remove carbon dioxide from the air.

Food in Space

For long space flights, a large supply of food will have to be carried. You know that many foods spoil in a short time.

Scientists have found some ways to preserve certain foods. One way is by **irradiation** (ih-ray-dee-AY-shun). The foods are placed in a special container. Strong ultraviolet and X rays are passed through the food. The rays do not seem to harm some food. The rays keep such food fresh for years without refrigeration.

Another way to preserve food is called **freeze-drying.** First the food is frozen. Then it is placed in a machine that removes the frozen water from the food. The dried food lasts for a long time.

- *Which preservation methods are practical for space?* (Dehydration or concentration into food pills, etc., which remove most of the bulk from the food.)
- *Water is vitally important to life. Is it not somewhat contradictory to remove something we will need to supply anyway?* (Rhetorical question, although pupil response might dictate otherwise. In a limited space, all the water in the system must be used again or it must be recycled.)
- *Where will water be, or come from, in the spaceship?* (The cooling system of the capsule, the algae, and the astronauts will have water.)
- *Where will humidity come from?* (Remember that the cooling system is closed. The humidity will come from the astronauts, mainly. Evaporation from the algae can be controlled by enclosing the system.)
- *How will humidity come from the astronauts?* (Remember oxidation, the process of extracting energy from the food we eat. The formula, considering the food to be glucose, is:

$$C_6H_{12}O_6 + O_2 \longrightarrow \text{energy} + CO_2 + H_2O$$

Remember also, an important function of the skin is regulation of body temperature by evaporation of water.)

• *There will be, therefore, plenty of water in the space capsule that will have to be disposed of. How?* (One economical way, from the weight standpoint, is to recycle the water.)

Background: Answers to the *Questions to Think About,* page 299, are:

1. Drops of water have condensed on the transparent paper or plastic bag.

2. The water does not taste salty. When sunlight evaporated the water, the salt was left behind.

○**ADDITIONAL ACTIVITIES:**

A variation of the experiment on page 296 may be attempted: Fill a large beaker, and a test tube, with previously boiled and cooled water to which a pinch of sodium bicarbonate ($NaHCO_3$) is added. (The water is boiled to remove dissolved gases. The "bicarb" is added to provide an adequate level of CO_2 gas in the water.)

Water for Space Travelers

Space has no water. Without a supply of drinking water, human beings would not be able to make long space journeys.

Scientists do not know exactly how much water will be needed. They believe that each person will probably be able to survive with an average of two quarts of drinking water daily. The amount will depend on two factors—the temperature inside the spacecraft and the activities of the traveler. Can you explain why?

One way of solving the problem of water for space voyagers will be to use a small supply of water over and over again. After the water is used, it may be purified in several ways. One way is by evaporation. Try the experiment on page 299 to see how this might be done.

In the experiment, heat from the sun changed some of the water to water vapor. The vapor condensed on the wrapping. The drops of water were not salty. The salt remained in the liquid in the pan.

By evaporation, dissolved substances can be removed from water. In this way, water may be purified in space and used over and over again. How does this compare with the way in which we get fresh water on earth?

Danger from Light

Space is dark. From the earth the sky appears blue because light is reflected from particles in the atmosphere. In space there are no particles to reflect light. The sun is a blazing light, and the other stars shine brightly in the sky. The space around these objects is black.

When a spacecraft enters space, the light may enter a window and be reflected inside the ship. The cabin will be a dazzling contrast to the darkness outside. The contrast will be much greater than we are used to on earth.

The human eye can adjust to light and dark. Observe someone's eyes when the amount of light is suddenly changed. Watch the pupil adjust to light.

A spaceman has to be very cautious about his eyes. When he faces away from the sun, there is almost complete darkness. The pupils of his eyes adjust by opening wide. If he quickly turns his head toward the bright part of the spaceship, it could be dangerous.

How do your eyes feel when you walk from darkness into bright sunlight? Of course, spacemen are carefully trained never to look directly at the sun. Looking at the sun would be painful and harmful. Scientists do not know yet how eyes will be protected in space. This is a problem that must be solved.

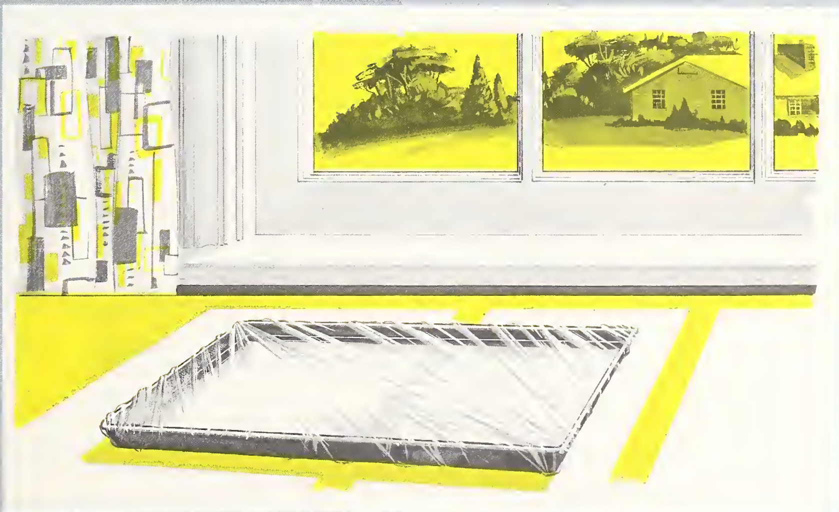
How Can Water Be Purified by Evaporation?

What You Will Need

flat baking pan
1 tablespoon of salt
1 quart of water
transparent food-wrapping paper or plastic bag

How You Can Find Out

1. Dissolve the salt in the water and taste the solution.
2. Pour the solution into the pan.
3. Cover the pan carefully with the transparent paper or a plastic bag.
4. Place it in sunlight for several hours.



Questions to Think About

1. What did you notice on the paper covering the pan?
2. Slowly remove the paper and taste some of the drops. Describe their taste. How do you explain the change?

Get 8 or 10 fresh cut sprigs of Elodea or Cabomba (common aquarium plants), and place them, cut side up, into a funnel, which is placed in the beaker under the level of the water.

Invert the filled test tube over the glass stem of the funnel, so that the entire system is filled with water.

Shine a strong light on the setup, to encourage photosynthesis.

The gas bubbling up and collecting in the test tube is oxygen. If this setup is constructed early in the day, there should be enough oxygen collected after several hours to give a positive reaction to the test for oxygen—a glowing splint inserted into the inverted test tube will burst into flames.

TEACHING SUGGESTIONS

(pp. 300–302)

● **LESSON:** What dangers does man face in space travel?

Background: Space is filled with many kinds of radiation. Most of this radiation never reaches the earth, because it is stopped by the atmosphere. Light, of course, is one kind of radiation that does penetrate the atmosphere; some radio wavelengths also touch the earth. But most radiation, including the most harmful, is scattered, absorbed, or broken down into less energetic secondary radiation by the atoms of the upper atmosphere. When man ascends into space, however, he will leave the protecting atmosphere behind.

Learnings to Be Developed:

Man in space must never look directly at the sun.

Space travelers must be shielded from the particles of cosmic rays and solar flares.

The radiant energy of the sun must be controlled.

Developing the Lesson: Recall Dr. Piccard's experiments with cosmic rays (pages 269–270).

- *If there are cosmic rays in the stratosphere, are there also cosmic rays in space?* (Yes.)

Danger from Other Radiations

Space contains deadly rays. Our atmosphere protects us from these rays. Out in space two kinds of radiations may be fatal to space travelers. You know about cosmic rays in space. These rays are very strong. They can pass through many inches of lead. No one knows how long a man can survive when exposed to cosmic rays in space. The first astronauts did not orbit high enough to pass through the dense cosmic-ray belts. Scientists are studying astronauts to learn about the effects of low exposure to cosmic rays.

Other dangerous rays come from the sun. These rays are produced by **solar flares.** Satellites helped scientists discover these rays and measure their strength. From time to time these flares send thick streams of atomic particles and dangerous rays far into space. If these particles strike the walls of spacecraft, people inside may be killed. As scientists study the sun, they search for more information about solar flares. If flares can be forecast, space flights will be delayed until the danger is past.

Protection against dangerous radiation in space is a difficult problem. How will it be solved? Scientists will have to find a solution to this problem before men can travel safely in space.

Great streamers of glowing gases, called solar flares, shoot out from the sun.

Danger from the Sun's Energy

Space has no heat. Does this surprise you? After all, the sun shines on the entire solar system. Energy from the sun travels through space. But this energy must be absorbed by something to produce heat. If there is nothing in space to absorb the sun's energy, there is no heat.

On earth, the atmosphere protects us from the intense energy of the sun. In space, there is no natural protection. Some of the sun's energy will be reflected from the spaceship. Some will be absorbed and cause heat inside. The spaceship will have to be constructed

How Do Dark and Light Colors Affect the Absorption of Heat Energy?

What You Will Need

3 metal cans of the same size	black and white tempera paint
3 room thermometers	soil

How You Can Find Out

1. Paint two cans white and one black. Let the paint dry.
2. Paint black stripes from top to bottom all the way around one of the white cans. Now you have white, black, and black-and-white-striped cans.
3. Put one inch of soil in each can.
4. Carefully place a thermometer in each can.
5. Add more soil around each thermometer until the cans are about two-thirds full.
6. Make sure you do not cover all the numbers on the thermometers.
7. Read the temperatures and keep a record of them.
8. Now place the cans in bright sunlight.
9. Use a heat lamp if the sun is not bright enough.
10. Take temperature readings at 5-minute intervals for 30 minutes. Record your readings.

Questions to Think About

1. How did your results compare after the observations were completed?
2. Do dark and light colors differ in the amount of heat energy they absorb?
3. If you found that the cans did not heat at the same rate, tell which one heated the fastest. Which heated more gradually? Can you explain your results?
4. Using striped surfaces may be one way to solve the problem of temperature control in spaceships. Can you tell why?

- *Why should the light of the sun be dangerous?* (The pupils of the eye accomodate to light conditions. They open to let in more light when it is dark; they close down when it is bright. But if too much light suddenly entered the eyes, the pupils might not be able to accommodate in time, and one might become temporarily or even permanently blind.)

The scientists have one solution to this problem. They have invented a compound that darkens when exposed to light and when the light lessens. By coating the astronauts' faceplates with this compound, the problems of too much light might be overcome. The darkness of the viewing faceplate would adjust automatically, and more swiftly than the pupil, to variations in light.

- *What two kinds of radiation are in space?*

- *Would it be possible to protect men in space by coating spaceships with several inches of lead?* (Possible, but not feasible. The weight of the lead would be too great.)

Most of the particles that threaten life in outer space have a positive or negative charge. This means that they can be deflected by the right kind of magnetic field.

- *Why is there no heat in space?*
- *If one were to put a thermometer outside a spaceship, would the thermometer register heat?* (Yes. It would absorb the sun's energy and heat up.)

Background: The answers to the *Questions to Think About* on page 301 are:

1. The black can showed the highest temperature. The white can showed the lowest temperature. The striped can showed an intermediate temperature.

2. Yes.

3. Dark surfaces absorb more energy than light ones do.

4. The number of dark stripes on a spaceship would determine the amount of the sun's energy absorbed. This in turn would determine the ship's temperature.

A light object reflects energy better than a dull one. A dull object absorbs heat.

If a ship were completely reflective, it would not absorb enough energy for comfort; if it were completely black, it would absorb too much energy for comfort. So by painting black stripes of the right number and size, it is possible to have the spaceship absorb just the right amount of energy.

This is one artist's idea of what a space refueling station might look like.

so that it absorbs just the right amount of energy for comfort. Otherwise it will be impossible for the passengers to remain alive.

How might this be done? From experiments, you have several clues to the solution of this problem. Which reflects energy better, a light object or a dark one? Which absorbs more heat, a shiny object or a dull one? On spaceships, a careful balance of materials may help solve the problem of heat.

One solution that has been suggested is to paint the spaceship with black stripes from front to back. Will this solution have any effect on how much heat energy is absorbed?

Space Stations

Rocket ships will not be able to carry all the fuel they will need for long trips. Space stations will probably be built where rocket ships can refuel. These stations would be constructed somewhere beyond 300 miles above the earth. Can you tell why? They will revolve around the earth in a fixed orbit, just as the moon does.

At a distance of 1,050 miles beyond the earth, such a space station will have to go around the earth at a speed of almost 18,000 miles per hour. At this speed, it will be pulled toward the earth in a curved path so that it will never hit the earth. Instead, it will remain in orbit.

How is this spacecraft being slowed down? Why must it be slowed down?

Space stations might be built in the shape of a ring. If the station spins slowly, people inside the ring will feel the effects of circular motion. The forces will be like those in a centrifuge. In this way, artificial gravity will be produced in the space station.

Because of the absence of gravity as space stations orbit the earth, things in them would be weightless. Rockets leaving the stations for long space flights would not need as much power to leave as they needed to overcome their great weight at the surface of the earth and leave the earth.

Earth-launched rockets must climb through the atmosphere to reach space. They must be streamlined so that the air flows around them. But in space, air friction is no problem. Rockets launched from space can be built in any shape that is best for the long trips.

Returning to Earth

Sooner or later, voyagers will have to return from space and land on the earth. Far out in space, the earth's gravitational force has very little effect on a spacecraft. As the spacecraft nears the earth, however, the gravitational force becomes greater. The ship goes faster and faster. Close to the earth, it may travel as fast as 7 miles a second. Small rockets attached to the spacecraft

TEACHING SUGGESTIONS
(pp. 303–305)

LESSON: How will interplanetary voyages be made?

Learnings to Be Developed:

Interplanetary rockets will probably fuel up for their voyage at space stations in orbit around the earth.

When the spaceship returns to earth, it will slow down by the use of rockets and through friction with the atmosphere.

Developing the Lesson: Space stations will be constructed above the atmosphere. This will bring many advantages to astronauts and physicists. At this altitude the drag of air on the space station will be negligible. The orbit of the space station will not decay, and the space station will not fall back to the earth.

- *Why should men build the space station in the form of a ring?* (So that uniform artificial gravity can be created by rotating the ring.)
- *What advantages would a rocket launched from a space station have over a rocket launched from the earth?*

The rocket shown on page 303 is slowed down by its parachute.

This is the final stage of descent from outer space; rockets have served to decelerate it to a few hundred miles an hour; the parachute will ease it gently to the earth.

- *At what speed will an unhindered rocket hit the earth?* (At 7 miles per second.)
- *How does this speed compare with the rocket's escape speed?* (They are the same.)
- *Can you think why they are the same?* (Escape speed is a way of expressing the amount of energy needed to overcome gravity. Gravity will pull the ship backward unless the ship moves at 7 miles per second. So, gravity is a backward acceleration (a deceleration) of 7 miles per second acting on a spaceship. But when the spaceship is traveling back toward earth, and no longer fighting gravity, the force acts to accelerate the ship to 7 miles per second.)
- *What would happen to the spaceship if it did not enter the atmosphere at an angle?*
- *What part does friction play in slowing down the spaceship?*
- *What are the two methods of reentering the atmosphere? How do they differ? How are they the same?*

will be used to slow it down. It will then be guided into a landing path so that it will enter the atmosphere at an angle rather that shoot directly down toward the earth. Because it enters at an angle, the spaceship will go through the denser parts of the atmosphere gradually. The friction, which will slow down the ship, will also cause it to become very hot. Some way must be found to keep it from burning up as it re-enters the earth's atmosphere.

Scientists are now testing two methods of re-entering the atmosphere from space. The Mercury capsule has a special fiber glass shield on the bottom. As the capsule speeds into the dense air of the atmosphere, the shield becomes red hot. It starts to melt from the friction. But inside the capsule the astronauts do not feel the 3,000° C. temperature. In minutes the friction slows the capsule to a few hundred miles an hour. Then a parachute lands it gently on the water.

The other method of landing is being tested by the X-15 rocket plane. This plane has two skins. The outside skin is a special metal that will not bend or soften from heat. The inner skin and the cabin are kept cool by a special refrigerator. Wings allow the X-15 to glide into the atmosphere very gradually. It loses speed slowly. Air friction during a slow descent is not great. In the lower atmosphere, the rocket plane is controlled and landed like a regular plane.

Interplanetary Travel

Soon man will journey to the moon and return. You know that many problems must be solved before such long voyages in space are undertaken. Then human beings may travel to nearby planets. Scientists believe this may happen in your lifetime.

Space travelers will have to be alone in space for a long time. How will they get along separated from their families and friends? Can man adjust to living in the silence of space? No one knows. But every day, scientists are testing ideas to find the answers.

Attached to the large aircraft is the X-15 rocket plane. Why is it attached in this way?

Using What You Have Learned

1. Make a list of things that you do that depend on gravity. Check each one that you would have to do on a space journey. How would you do these things?

2. Experiment to find out how much oxygen your aquarium plant can make in a week. Use the same equipment that you used for the experiment on page 296. Every day blow some carbon dioxide through a straw into the water. Measure the amount of oxygen collected in the test tube daily. Make a graph showing how much gas was produced.

3. Read and report on the first manned flights into space. A librarian will help you find information in books and magazines. Look for this information: How long did the flight last? How were the men dressed? What experiments did the men have to do in space? What were their experiences with weightlessness? What did they discover about space? How was the capsule made to re-enter the earth's atmosphere?

4. *Nova* and *Saturn* are two launch rockets planned for future space flights. Read and report about them. Look for the following information: What is a *booster?* What job is each booster designed to do? How much thrust will each booster develop? How big a load will each be able to place in space? What fuels are now being considered for use in these rockets? How tall will each launch rocket be?

5. Paths to other planets will not be ellipses. What will the paths be like? Look this up in books about space travel, such as *Orbits* by Hy Ruchlis.

6. Imagine you are an astronomer working on a space station that orbits the earth. What advantages would you have in making your observations of the skies from space?

The X-15 pictured on page 304 is attached in the fashion shown so that it can be dropped and fly on its own. This X-15 is carried aloft by the larger plane so that the rocket plane does not waste its precious fuel in overcoming the heavy air of the lower atmosphere.

Background: The answers to *Using What You Have Learned* are:

1. Most simple actions depend on gravity: walking and sitting, for instance. In a gravitationless environment, one could not walk; he might propel himself through the air by pushing from wall to wall or from floor to ceiling. One could sit in the middle of the air.

6. An astronomer would be able to observe the entire electromagnetic spectrum, not merely the radio and light frequencies. His telescopes would have vastly improved resolution; his photographs would have unlimited exposure time and would not show the distorting effects of the atmosphere. He would be able to measure directly the radiation of solar flares; he could count the number of cosmic rays approaching the earth. The advantages of an orbiting astronomical observatory are so many and so great as to make one almost inevitable in the near future.

TEACHING SUGGESTIONS

(pp. 306–307)

Background: These two pages constitute a review of the concepts and terminology introduced in this unit.

What You Have Learned: This is a summary of the entire unit, with new words in boldface type.

Checklist of Science Words: Remind the pupils that there is a *Dictionary of Science Words* on pages 358–364. They should consult this dictionary whenever they are unsure of the precise meaning of a word.

WHAT YOU KNOW ABOUT

Probing Outer Space

What You Have Learned

Rockets and **satellites** are man's newest means to explore the universe. Great forces are needed to send rockets into space. The force of a rocket engine is called its **thrust.**

To reach the great speeds necessary to place spacecraft in orbit, scientists use **multistage rockets,** made up of two or more rockets.

Spacecraft that explore far into space are called **space probes.** To launch such a probe, powerful engines boost the spacecraft's horizontal speed to about 7 miles a second—the **escape speed** from the earth. At this speed, spacecraft escape from the earth.

Astronauts feel **weightlessness** when they travel in space. During lift-off and re-entry the astronauts experience **G forces.**

Scientists are trying to lessen the effects of weightlessness and G forces in space by studying **artificial gravity** made by **centrifuges.**

In space, astronauts must be protected from **cosmic rays** and the rays from **solar flares.** They also have food problems. Scientists are studying **irradiation** and **freeze-drying** of food.

Because rocket ships will not be able to carry all the fuel that will be needed for very long space trips, space stations will probably be built where the rocket ships can refuel.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

action-reaction	escape speed	rocket	space probe
cosmic rays	G force	solar flares	thrust

Match the Scientists with Their Work

Number a page in your notebook from 1 to 5. Look at the list of names below and match the scientist to his work as given in the list below the scientists' names.

a. Robert Goddard
b. Colonel Stapp
c. Montgolfier brothers
d. Captain H. C. Gray
e. Auguste Piccard

1. Developed hot-air balloons
2. Gave scientists a better idea of temperature in the atmosphere
3. Went 51,000 feet in a closed gondola
4. Developed the liquid-fuel rocket
5. Went over 600 miles per hour to test G forces

Complete the Sentence

Write the numbers 1 to 5 in your notebook. Next to each number, write the answer that best completes each sentence below.

1. The force of a rocket engine is called the ___?___.
2. Spacecraft that explore far into space are called ___?___ ___?___.
3. High-speed atomic particles that come from outer space are called ___?___ ___?___ .
4. Spacecraft that go into orbit are called ___?___.
5. Scientists are trying to produce oxygen inside spacecraft by using tiny green plants called ___?___.

Match the Scientists with Their Work:

1. c
2. d and e
3. e
4. a
5. b

Complete the Sentence:

1. thrust
2. space probes
3. cosmic rays
4. satellites
5. algae

TEACHING SUGGESTIONS
(pp. 308–309)

Background: These pages reinforce the concepts presented in the unit by suggesting activities that extend the pupil's ability to apply the learnings derived from the unit.

ADDITIONAL ACTIVITIES:

Have your class observe the effects of air pressure. Demonstrate that air pressure inside a space suit or spacecraft must be regulated for man to survive in space. To do this you will need a balloon, a rubber band, a baby bottle, and a hot plate.

Blow up the balloon just enough to make the walls stand out (so that air pressure inside the balloon equals the air pressure outside the balloon). Tie the neck of the balloon with a rubber band. Next fill the baby bottle with a half cup of water and place it in a container of boiling water. Now put the container on the hot plate and heat it until the water inside the baby bottle starts to boil. When the water is boiling rapidly, drop the balloon into the baby bottle and cap the bottle tightly. Then remove the bottle (using forceps) from the container of boiling water and hold it under a stream of lukewarm water.

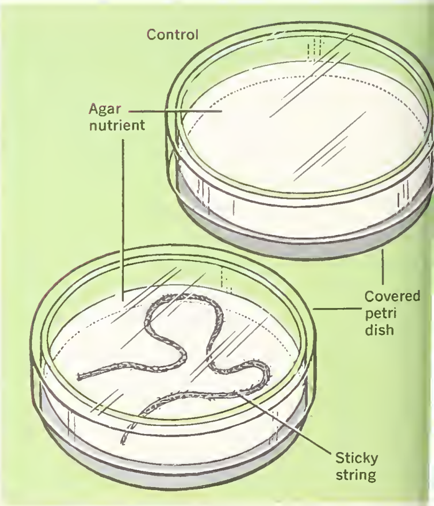
YOU CAN LEARN MORE ABOUT

Probing Outer Space

Try This

To find out if there is life on other planets, space probes may use the *Gulliver* or *sticky string* method. After a spacecraft lands on a planet, a sticky string or tape will be unrolled to pick up whatever is on the planet's surface and bring it back to the spacecraft. Inside will be nutrients necessary for the growth of living organisms. If there is life and it can use the nutrients, this information can be radioed back to the earth.

To get an idea of how the sticky string will work, sterilize some petri dishes and pour in agar to ⅛ inch. Cover and let cool. Drag a few 8-inch pieces of damp sterilized string across the floor or lawn. Next, place them in the agar. Use one petri dish as a control—that is, do not place a string in it. Cover each dish and keep in a warm place for a few days. *Do not open them.* Observe the dishes each day and keep a record. Do you see any life?



Do any forms of life grow on the control? Does the experiment show that all living things that are on the nutrient have been detected? From this activity, can you tell what living things need for growth?

Keeping a Spacecraft Log

On a large sheet of paper make 4 columns as you see in the picture. In the last column, under the heading *Purpose,* write how spacecraft put to use our scientific knowledge to make our world a better, safer place in which to live. As you keep your chart up-to-date, think about some problems on the earth that might be solved with greater knowledge about space.

SPACECRAFT LOG

Name of Spacecraft	Date of Launch	Type of Spacecraft	Purpose
Tiros VII	June 19, 1963	Weather satellite	To take pictures of earth's cloud cover. To increase man's ability to predict the weather.

You Can Read

1. *Guide to Rockets, Missiles, and Satellites,* by Homer E. Newell. Descriptions of spacecraft with many photographs.
2. *Robert Goddard: Space Pioneer,* by Anne Perkins Dewey. A biography of the father of the liquid-fuel rocket.
3. *Space in Your Future,* by Leo Schneider. A clear description of our physical world, the universe, and the advances we are making in space.
4. *All About Satellites and Space Ships,* by David Dietz. This book serves as a good summary of man's plans for space exploration.
5. *Experiments in the Principles of Space Travel,* by Franklyn M. Branley. Simple experiments show how the basic physical laws are being applied to space travel.

- *What happens to the balloon inside the bottle?* (It expands.)
- *What has happened to the pressure inside the bottle?* (The pressure has decreased and the air inside the balloon has expanded to equalize the pressure.)
- *What would happen to man in in space if there were no protection from lack of pressure?* (The gas inside his body would expand and he would blow up. The gas that is dissolved in his body would come out of solution and escape, causing a condition that deep sea divers get, called the "bends.")
- *How can man protect himself from lack of pressure in outer space?*

Discuss with your pupils the many by-products of the space age. For example, space-age technology has led to the discovery of new medicines, methods, and equipment that have application in hospitals. It has also led to new products for home use. Industry has been affected by space-age equipment and processes. New careers have been created in the professions, as well as new businesses and industries. Find out how many of the youngsters' parents are working in related fields.

KEY CONCEPTS

Key Concept 1. Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

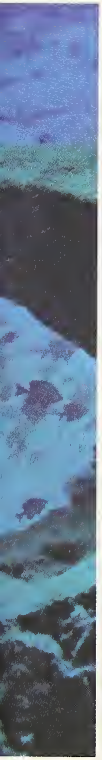
Key Concept 2. Lawful change is characteristic of events in the natural environment; although living things tend to produce living things like themselves, over millions of years the earth and living things on the earth have changed, and diversified forms of life have evolved.

Key Concept 6. There is a basic tendency toward stability or equilibrium in the universe; thus, energy and matter may be transformed, but the sum total of matter and energy is conserved.

Key Concept 10. Man has changed and continues to change the natural environment; but because he is often ignorant of long-range consequences, his actions may have harmful effects for himself and for other living organisms.

CONCEPTS:

1. There are many reasons why scientists study the ocean, but the most important one is because they are curious.



9

Other concepts appear under "Learnings to Be Developed" in each lesson found in the Teaching Suggestions.

Probing the Oceans

Man Explores Under Water

The Ocean Environment

The Balance of Life in the Oceans

2. Much of the earth is covered with water, and not much is known about what lies beneath it.
3. Scientists believe that the earth is very old and that oceans formed from water in the earth's atmosphere.
4. Because of great pressures at the bottom of the ocean, much of the evidence regarding it has been obtained indirectly.
5. There are many environments in the ocean, and they are constantly changing.
6. There are many substances dissolved in ocean water.
7. Ocean currents result from differences in temperature of water and surface winds.
8. Ocean life is adapted to the conditions in which it lives.
9. Scientists believe that life on earth got its start in the oceans.
10. There is a great variety of life in the ocean, and it exists in great abundance.
11. Oceans may someday be used as a major source of food and minerals.

PROCESSES:

- Observing—Page 351.
- Inferring—329.
- Selecting—329, 338, 351.
- Communicating—351.
- Demonstrating—314, 329, 338.
- Explaining—329.
- Hypothesizing—331.

TEACHING SUGGESTIONS
(pp. 312–313)

LESSON: What is oceanography?

Background: Though oceanography is a young science, it has already presented man with a host of intriguing problems and many potential solutions to world needs for minerals and other goods.

Learnings to Be Developed: Although the oceans are more extensive than the land in surface area, they are small in volume when compared with the entire earth. The oceans are potential sources of food and probably hold the secret of the origins of life on this planet.

Developing the Lesson: Have the children read the section, "Man Explores Under Water" to the bottom of page 313. Then ask:

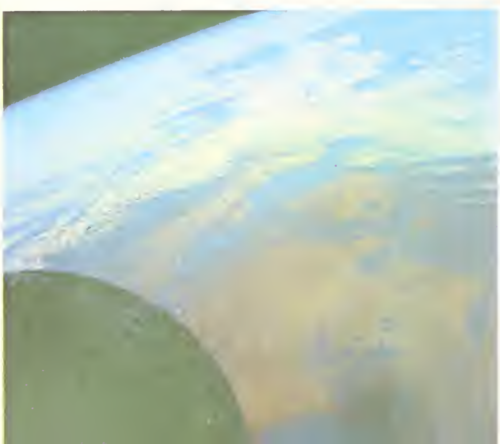
- *What is oceanography?*
- *Why, do you think, is it a young science?* (It is a young science because only recently has the technology of underwater exploration been developed. Efficient submarines are a very recent development; sonar, the bathyscaphe, and the aqualung are more recent still.)
- *Is there more land than ocean on the surface of the earth?* (No, about three-quarters of the earth's area is covered with water.)

Look at the photograph of the planet earth from 100 miles above it. This is how the earth looks to an astronaut. The dark areas are the oceans. Three fourths of the earth is under water. Great challenges are ahead for underwater explorers, because beneath the oceans lies a little-explored world.

Man Explores Under Water

The study of the oceans and seas is called **oceanography** (oh-shun-OG-ruh-fee). Oceanography is a young science compared with biology, chemistry, or physics. It offers exciting opportunities to boys and girls who are thinking about a career in science. In this unit, you will learn of some of the challenges that lie ahead for those who study the oceans.

Have you ever gone on a long automobile trip or train ride? Did you ever see land for as far as your eyes could see? Perhaps you think the amount of land on our planet is tremendous. An astronaut would not agree with you. When he looks down from high in the sky, he sees water—lots of water. Land is so important in our lives that we for-



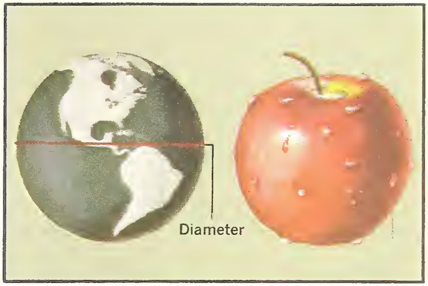
This photograph of our planet was taken from a spacecraft. Can you tell which areas are land masses and which are water? Which areas cover more of our planet?

get that the continents of the earth are islands in a very large body of water. We have used the oceans for food and transportation, but we have always stayed on or near the surface of the water.

To get an idea of how much land there is compared with the oceans, think of this: If the land were scraped off, ground up, and spread over the surface of the earth, the earth would be completely covered by water one to two miles deep.

Now you think that the oceans are tremendous. That is true, but only because you are so small compared with the oceans. If you compare the depth of the oceans with the earth's diameter, which is 8,000 miles, you would find that the oceans are like the thin film of water that clings to an apple after it has been washed.

Why do scientists want to explore the oceans? The most pressing problem on earth is to feed the increasing population, which is using up the supply of natural resources on land. To meet this challenge, man must turn to the sea as a source of food. The oceans may provide great quantities of materials. The oceans may also help man answer questions about how the earth and living things came about: How did life begin



The depth of the oceans is small compared with the earth's diameter. Think of it as a film of water on an apple that has just been washed.

in the oceans? How did living things develop to their present stage? How are living things still changing? The oceans may provide some answers to questions about the natural history of the earth.

These are some of the reasons that man studies and explores the oceans. But there is another reason—one which is just as important. Man is curious. Just as man wants to know about outer space, he wants to know about the oceans. For each question scientists answer, a dozen others are raised. The more we find out about our planet, the more we realize how much we do not know! Scientists go on developing theories which lead to answers while, at the same time, nature provides a seemingly never-ending supply of new problems for scientists to solve.

Refer to the picture on page 312. The land masses in the picture are brown, the ocean blue. The white streaks that cover the upper third of the picture are the cloud cover. If the pupils look carefully, they can see that there is water beneath the clouds.

The theoretical ocean described in the second paragraph on page 313 would have a depth of 8,000 feet.

How does this compare with the earth's diameter of 8,000 miles?

What is the ratio between them? (The ratio is 1 mile to 1 1 foot, or 5,280 to 1.)

If the apple in the illustration on page 313 had a diameter of 5 inches, how thin would the film of water be? To simplify our calculations, let's assume that the ratio is 5,000 to one. Write:

$$5{,}000:1 = 5:x$$

$$5{,}000\,x = 5$$

$$x = \frac{5}{5{,}000}$$

$$x = \frac{1}{5{,}000}\text{ inch}$$

Why should we study the oceans of the earth?

TEACHING SUGGESTIONS
(pp. 314–318)

LESSON: How have men explored the oceans, and what have they learned?

Background: The origin of the oceans is still somewhat controversial, although certain features have been adequately accounted for. When the earth was formed some 3–5 billion years ago, it was a molten ball. It cooled like a dessicating orange, its skin becoming more and more wrinkled as the interior shrank. In this manner the ocean basins were formed.

There are other hypotheses, however. One of them suggests that the moon was formed when the earth spun off a part of its mass during this cooling period, and that the scar of that gigantic upheavel is the basin of the Pacific Ocean.

Another hypothesis holds that the continents of the world are receding from one another. The ocean basins are, then, created as this vast motion takes place.

Learnings to Be Developed:

Oceans originated several billion years ago.

Scientists can explore shallow depths using an aqualung; they

How the Seas Formed

Four and a half billion years ago, the earth was hot, round, and pock-marked. There was no land, no water, no atmosphere as we know it, and, of course, no life.

As the surface of the earth cooled, it slowly shrank. Can you guess what happened to the surface? The surface became wrinkled.

During the millions of years that the surface of the earth was cooling, water vapor in the atmosphere condensed into water and fell as rain. At first, the rain turned to steam as soon as it hit the hot rocks. This went on for a long time, until the earth cooled enough so that the rain did not immediately evaporate. Instead, some of it remained as water and filled the lower areas to form the oceans. If the surface of the earth had been smooth instead of uneven, a blanket of water would have covered the whole earth. That blanket would have been about 8,000 feet deep!

Although we are not certain about how the earth was formed, we are certain that it took a long time.

For many reasons, the surface, or crust, of the earth is still changing slowly. One reason is rainfall. As water runs off the land, it picks up soil and dissolves minerals from the rocks. Some

This picture shows how scientists think the seas may have formed on our planet.

of this water flows into lakes and rivers. Rivers flow into oceans, carrying soil and minerals.

As materials are moved about on the surface of the earth, the earth's crust settles in some places and rises in others. Sometimes changes take place swiftly, as in an earthquake, for example. However, most changes are very, very slow.

Look around you. You may be able to find evidence of some of these changes. Try to find pebbles that have been made smooth by flowing water, or a hillside that has been worn by water.

Special aqualung equipment has been used to permit man to dive several hundred feet below sea level.

Exploring the Unknown

Ocean waters hide the shape of the sea floor. The waters make it difficult to drill into the sea floor. They cover the layers of animal remains that would provide scientists with more information about the history of the earth.

To see through the oceans, scientists must use special instruments and special vessels. They must be able to go down into the water to see for themselves. It is only in the past few years that scientists have been able to explore the ocean floor. Until then, scientists used instruments that collected and measured samples from the surface of the water.

Why has it been so difficult for man to go beneath the surface of the waters? One reason is that man cannot breathe under water without special equipment. The **aqualung** has helped solve that problem by permitting man to dive as low as 40 feet below sea level. This is called skin diving or free diving.

Skin diving has many advantages over helmet diving, in which the diver wears a bulky suit and a heavy metal helmet with windows to see through. Air is pumped through the tubes attached to the helmet. A ship is stationed above the diver to feed him air and to pull him up. In helmet diving there is always the danger that something may happen to

There are many beautiful sights to see and there is much to learn when you know how to skin dive. Skin diving should never be tried without the aid of an expert.

Discuss operation "Sealab" with your pupils. Note astronaut Scott Carpenter's involvement in this project as a member of the underwater research team. Compare Carpenter's comments about his underwater experiences with his outer space experiences. Refer pupils to back issues of August and September 1965 newspapers for details.

can go deeper using deep-sea diving equipment, and deeper still in a bathyscaphe.

They also use reflected sound waves to measure ocean depths.

The ocean is divided into continental shelves, continental slopes, and floors, each deeper than the last.

Developing the Lesson: Start the lesson with a discussion. If any of the children has ever taken a sea voyage or flown across the ocean, let him tell about the experience.

- *How did all that water get there?*
- *When did the oceans form?*

Have the children read "How the Seas Formed," and then review that section.

- *How long ago did the earth form?* (At least 3–5 billion years ago.)
- *Why didn't the earth shrink into a smooth ball?* (The earth is made up of different materials. Different materials cool and shrink at different rates. So some materials were pressing against others, and some were leaving open spaces behind them. The stresses buckled and warped the surface of the planet.)

How cool did the earth have to become so that the rain would not immediately evaporate? (The temperature had to fall below 212° F.)

Have the section "Exploring the Unknown" read. Then refer to the picture on page 315.

What does the man have that allows him to breathe underwater? (An aqualung.)

What is on his back? (His oxygen supply.)

On his feet? (Flippers to help him swim.)

What is he doing? (He is taking a picture with an underwater camera.)

What advantage does an aqualung have over deep-sea diving equipment?

What advantages does deep-sea diving equipment have over the aqualung?

Point to the picture of the bathyscaphe *Trieste* on page 316. Make certain the children understand that the gondola is the white sphere underneath, not the submarine-shaped tank above. The walls and windows of the *Trieste* are thick because they have to withstand the tremendous pressures of ocean depths. Also, the gondola's spherical shape with-

This is the bathyscaphe *Trieste*. The steel ball on the *Trieste's* underside is called the gondola. The steel skin of the gondola is 3½ inches thick and the windows are of clear plastic about 5½ inches thick. Why are the walls and windows so thick?

the air tubes. Skin diving permits the diver to carry his oxygen with him. Another advantage is that the skin diver can swim like a fish and do much more than the helmet diver who is limited mostly to walking.

Skin diving has made it possible for scientists to make maps of the rocks on the floor of the ocean off California. Skin divers have seen landslides under the sea. They have observed and collected specimens of plant and animal life. They have also taken pictures under water.

The skin diver can see and move about at the shallow edges of the sea. The helmet diver or deep-sea diver can go down about 600 feet. But scientists must be able to plunge still deeper. In order to do so, they are faced with a problem. Water exerts pressure on objects that it covers. As you know, air exerts pressure, too, but air at sea level presses with only 15 pounds of force on every inch of the body. In the depths of the oceans, there is so much pressure against a man's body that he would die. He cannot withstand so much force.

The **bathyscaphe** (BATH-ih-skayf) is a deep-sea diving balloon that enables scientists to plunge to a depth of almost seven miles. It was invented by Auguste Piccard who, you remember, is famous as a balloonist.

In 1960, the bathyscaphe *Trieste* plunged successfully to 35,800 feet.

This was as great a triumph for science as the placing of a satellite in orbit.

The bathyscaphe works in water just as a gas balloon works in air. Iron shot provides the weight needed to sink the bathyscaphe to the bottom of the ocean. When the scientists wish to return, they simply release the iron shot. They have with them a tank filled with gasoline, which is lighter than water. This enables them to rise to the surface. Observers ride in a steel ball below the gasoline tank. They can control how fast they go up or down. While in the steel ball, the scientists look through windows, called ports. They take photographs and collect samples.

In 1964, Operation Deepscan took French and United States scientists more than four miles below the surface of the sea to study the deepest spot in the Atlantic Ocean, the Puerto Rico Trench. Their bathyscaphe, named *Archimède*, was 70 feet long by 26 feet high. It was built to dive seven miles. The vessel contained a submarine laboratory. It had equipment to measure the pressure, temperature, and speed of sound in water, and to collect samples of water, rock, marine life, bottom mud, and ooze.

When scientists descend to such depths, they have to be protected from the tremendous outside pressures of the

Observers get into the gondola by means of a tube 25 inches in diameter. In the gondola are many kinds of cameras, including television cameras, and many kinds of measuring instruments.

water. The bathyscaphe has a strong, watertight cabin that keeps the pressure of the air at 15 pounds per square inch, just as it is at sea level.

How do certain animals live with the weight of the sea against them? To live under such pressure, an animal must be adapted to it. The animal must have the kind of body structure that can stand the pressure. Animals that live in the great pressure of these depths would die if they were brought to the surface by ships. The change in pressure would kill them. They have to be protected against such changes in pressure. The bathyscaphe can keep them at their regular pressure and so bring them to the surface alive.

stands pressure better than other shapes. Have several pupils take a ping pong ball and, exerting pressure all over it, try to crush it. There are no corners or seams or projections to cave in. It is very difficult to do. So it is with the *Trieste's* gondola.

- *Can you see the similarities and differences between balloons and the bathyscaphe?*
- *How are they exactly unlike one another?* (Balloons rise, while bathyscaphes sink. Gondolas of balloons protect man from too little pressure, while bathyscaphe gondolas protect him from too much pressure.)
- *How are they alike?* (Both would carry along oxygen, food, and water for long trips. Both use the principle of buoyancy to rise, sink, or remain at one level.)
- *How do scientists control the descent and ascent of the bathyscaphe?*
- *Does the need to keep animals under pressure remind you of something you learned about man in space?* (Man, too, must maintain a certain pressure to live. See page 295.)
- *How did the scientists collect samples of life and sediment?*

- *How did the scientists aboard the bathyscaphe arrange to bring fish to the surface under pressure?* (In pressurized tanks.)
- *How has man learned about the deeper parts of the ocean?* (Scientists use sonar.)
- *Why does sound travel faster in water than in air?* (Because water is denser than air.)
- *Would sound travel faster in ocean water or in lake water?* (Ocean water, which is more saline, and so denser, than lake water.)

When the children have finished reading the section "The Bottom of the Ocean," ask:

What are the three parts of the ocean?

Why do plants grow mainly on the continental shelves? (The shelves are shallow enough to allow sunlight to reach plants growing there.)

The fish live on the continental shelves because they rely on the plants, directly or indirectly, for food.

How many feet deep is the trench near the Philippine Islands? ($5{,}700 \times 6 = 34{,}200$ ft.)

Man has seen the bottom only of the shallow parts of most of the ocean. However, scientists know much about the deeper parts. They have learned about these areas by using sound waves.

You know that when sound vibrations hit a wall, they are reflected as an echo. You can find out how far away a certain tall building or cliff is with a stop watch. Just shout a word and see how long it takes the echo to come back to you. Knowing that sound vibrations travel at about 1,100 feet a second, you can figure out the distance.

Scientists can find the depth of water by using the same method. Sound vibrations travel faster in water than in air. In water they travel about 4,800 feet a second. When vibrations are made at the surface of the water, the ocean bottom bounces or reflects them. Scientists can tell how deep the ocean is by measuring how long it takes sound waves to reach bottom and return to the surface.

The Bottom of the Ocean

The ocean bottom is divided into three parts. The **continental shelves** are the parts nearest the continents. It is believed that continental shelves were once above the water. They are the shallowest parts of the ocean. Sunlight can get through the water to almost all parts of

PATHFINDERS IN SCIENCE

Matthew Fontaine Maury

(1806–1873) United States

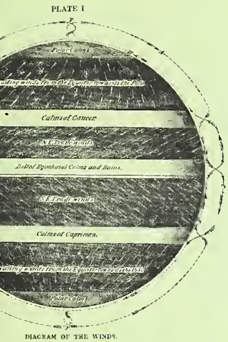
There is a saying, carved into a monument, that reads:

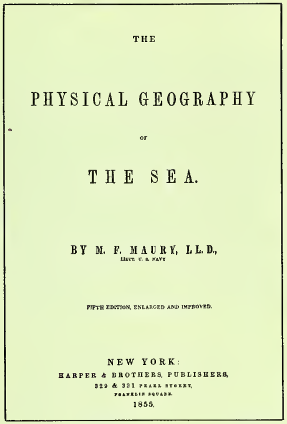
Matthew Fontaine Maury
Pathfinder of the Sea
The genius who first snatched
From ocean and atmosphere
The secrets of the Sea.

As a boy, Matthew Maury listened to his brother's adventures in the Navy. The games he played and the dreams he dreamed were of the sea. His favorite subject in school was geography, because it allowed his imagination to roam the world.

Knowing that he could not attend expensive schools, Matthew decided to join the Navy. In June 1831, Matthew was appointed a sailing master. As his ship sailed across the Pacific Ocean to the Orient, he wondered: Could sailing time be shortened if the winds and currents were used to aid the ship? He felt that the winds and currents must follow a pattern. Wherever the ship docked, Maury filled notebooks with his observations.

Lt. Maury was put in charge of the Depot of Charts and Instruments. He ordered all ships to gather information daily on lati-




THE

PHYSICAL GEOGRAPHY

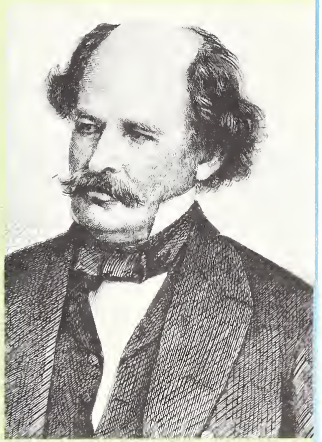
OF

THE SEA.

BY M. F. MAURY, LL.D.,
LIEUT. U. S. NAVY

FIFTH EDITION, ENLARGED AND IMPROVED.

NEW YORK:
HARPER & BROTHERS, PUBLISHERS,
329 & 331 PEARL STREET,
FRANKLIN SQUARE.
1855.



tude and longitude, hourly rate of currents, speed and direction of winds, temperatures, fogs, the sighting of whales and birds, and barometric pressure before, during, and after storms. He asked sea captains to throw into the water tightly corked bottles containing instructions for their return to the ships' headquarters. The purpose was to estimate the course and speed of the current that carried the bottles. As a result, routes were shortened and sailing times were cut.

Lt. Maury charted the currents of the oceans and proved that they are stable, have direction, and affect climate. He taught sailors how to navigate *with* the seas rather than against them.

In 1855, *The Physical Geography of the Sea* was published. It was written by a man afire with enthusiasm for oceanographic research. The book was used throughout the world. It gave proof of Lt. Maury's hard work, his keen observations, his insight into the many phases of the sea, and his ability to enlist the cooperation of so many.

The highest honor given to Lt. Maury was that the first great oceanographic expedition ship, the *Challenger*, was guided around the world by his charts. Today all charts issued by the United States Hydrographic Office say: "Founded upon the researches made by Matthew Fontaine Maury, while serving as a Lieutenant in the U. S. Navy."

TEACHING SUGGESTIONS
(p. 319)

Background: Maury was appointed a midshipman in the United States Navy in 1824, when he was 18 years old, and circumnavigated the world during a 4-year cruise of the U.S.S. *Vincennes*. In 1839, he was permanently lamed as the result of a stagecoach accident. Unfit for further active duty, he was appointed in 1841 to the post of superintendent of the Depot of Charts and Instruments, the precursor of both the U.S. Naval Observatory and the U.S. Hydrographic Office.

An energetic man, Maury set to work learning as much about the ocean currents and winds as possible. He distributed special logbooks to the captains of ships, which they were required to fill out as described in the text.

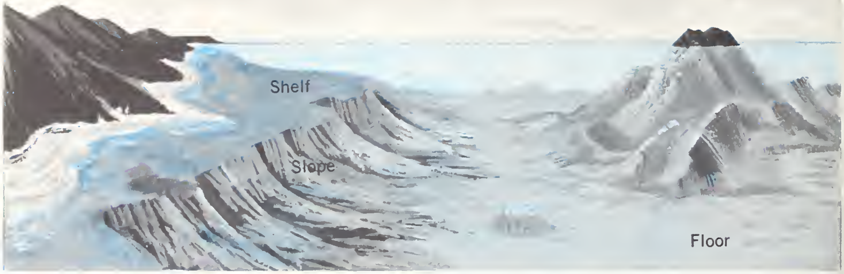
He accurately charted the courses of ocean currents, the Gulf Stream in particular, and thereby enabled ships to shorten the times of voyages considerably. In preparation for the laying of a transatlantic cable by Cyrus Field, Maury in 1850 charted the depths of the North Atlantic.

TEACHING SUGGESTIONS
(pp. 320–328)

Background: In the unit "Probing Outer Space," the pupil learned that man is now able to orbit the earth and send instruments toward the planets and stars. In "Probing the Oceans" the pupil learns of man's attempts to explore the deepest depths of the ocean. This picture story shows some of the first steps in man's exploration of the oceans. Man is only on the threshold of unlocking the oceans' untold treasures and opening this last planetary frontier for man's use, understanding, and enjoyment. Oceanography is one of the most challenging of today's science fields. The explorers of the oceans are physical, meteorological, and chemical oceanographers, marine taxonomists, and marine geophysicists.

The seas blanket more than 70 per cent of the earth's surface, but less than 5 per cent of this vast domain has been mapped. Only about 9 per cent, mostly on the continental shelves, has been even partially explored by man.

The sea is a huge storehouse of raw materials that has barely been tapped. Today, only about 1 per cent of mankind's food comes from the sea. Yet the sea, acre for acre, could yield animal and



THE BOTTOM OF THE OCEAN

the shelves. Plant life grows well in the water above the shelves. This is where most fish live. Can you see why?

The shelves drop suddenly into steeper hills, called **slopes.** At the bottom of the slopes, there are canyons and valleys.

The **floors** are the deepest parts of the ocean. They are so far down that man knows very little about them. They are a world of complete darkness. Do you think plants grow there?

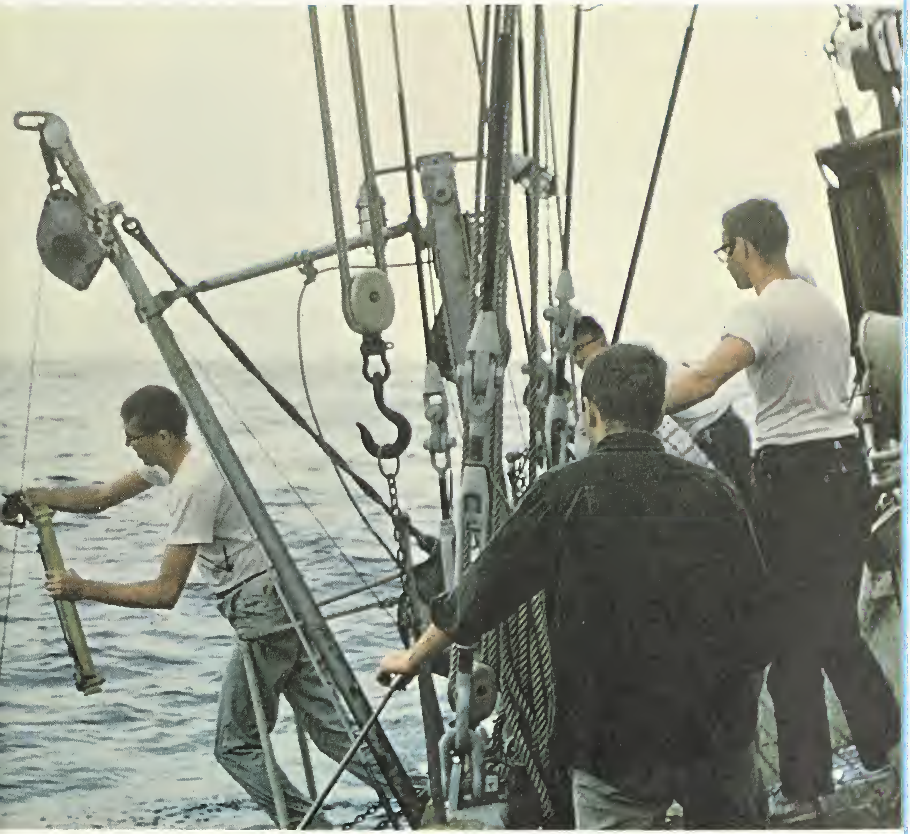
For a long time man thought that no animals lived in this world of darkness. How could they live without plants, without light, and under such great pressure? Today, we know from research-vessel dives, from echo-soundings, and from specimens that have been pulled out of the depths that there are animals living there.

The depth of the ocean is measured in **fathoms.** A fathom is 6 feet. One of the deepest parts of the ocean is a long trench near the Philippine Islands about 5,700 fathoms deep. The highest mountain on land is about 29,000 feet.

ABOUT "PROBING THE OCEANS"

In 1961, President John F. Kennedy said, "Knowledge of the ocean is more than a matter of curiosity. Our very survival may hinge on it." Yet, until the last few years, the study of the ocean has been a neglected science. Although there is now a great deal of research going on in oceanography, more needs to be done. There are many opportunities for those interested in the world's oceans. The next eight pages show you some of the work of oceanographers.

Probing the Oceans



food crops equal in value to those of the land. Today, man is still a hunter rather than a farmer of the sea.

All known chemical and mineral elements exist in the sea; yet only magnesium, iodine, bromine, salt, and a few other substances are commercially extracted from sea water.

Today we are faced with serious water shortages. Development of an inexpensive way to remove the salt so that sea water could be used for irrigation would help to transform millions of miles of desert land to farming land. Sea water could also constitute a source of drinking water to relieve the continual droughts that plague parts of the earth.

The movement of ocean water serves to regulate the climate on land and plays a large role in determining both long-range and daily weather changes. Hurricanes, typhoons and great storms begin at sea and often grow to destructive proportions before they are detected by ships, weather stations, or ocean weather buoys. Physical oceanographers believe that understanding the boundary between the sea and the air, called the *interface,* may lead the way to future weather control.

Oceanography is usually divided into ocean engineering and four major research areas: chemical, physical, biological, and geological.

Chemical oceanography: Chemical oceanographers study the chemicals found in the oceans. Because these chemicals exist in the same proportions in all oceans of the world, regardless of the total salt content, analysis for one element should provide information concerning the amounts of all. The major elements studied are sulfur, bromine, chlorine, fluorine, magnesium, potassium, calcium, strontium, and sodium. Perhaps one day it will be economically practical to mine these elements from the ocean waters.

Physical oceanography: Physical oceanographers study the physical properties of the ocean—the temperatures, waves, currents, tides, and rates of sound transmission. They may chart the streams and drifts of the waters at different levels; they are learning why the water movements are important, how they may influence weather, and how they may affect life on the continents.

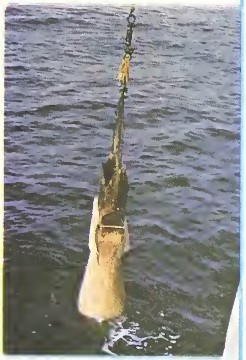
Biological oceanography: Biological oceanographers study the plants and animals that live in the ocean—from bacteria and one-

Most scientists interested in marine science work for oceanographic laboratories such as the Woods Hole Oceanographic Institution in Woods Hole, Massachusetts. These seashore laboratories, together with their research ships, carry on investigations in all areas of oceanography. The geophysical oceanographer studies tides, waves, oceanic circulation, and physical properties of ocean basins and of sea water. The marine biologist studies living things found in the sea.

Let's go aboard the research ship **Chain.** A day aboard the **Chain** begins early and ends late. Even while a few sleep, work goes on. The researcher's day never ends.

The large net being lowered is used to collect plankton samples.

It is late at night as another plankton net is hoisted from the ocean.



Plant and animal life are caught in the net of this bottom surface sampler.

Over the side goes a Nansen bottle to get samples of ocean water. A thermometer fastened to the outside of the metal bottle records the temperature of the water at various depths.

celled plants such as phytoplankton, which drift with the currents, to the blue whale, the largest living organism. They identify the various species of marine life to determine their distribution, habits,. and relationships. They seek information about the productivity of the oceans. Such studies are useful in gaining an understanding of the extent of marine food resources and what might be done to increase them.

Geological oceanography: The specialties of geological oceanographers include studying ocean-bottom topography, the patterns of the earth's magnetic field, heat transfer from the earth's interior through the ocean floor, natural and man-induced seismic or earthquake activity, the geological structure and mineral content of the silt and rock strata on and below the ocean floor, and the occurrence of fossils in the silts and rocks of the sea. These oceanographers include geologists, geophysicists, and geochemists. Their studies are basic to understanding the magnetism of the earth and the causes and results of magnetic forces.

If you choose to give your pupils an overview of the various fields of oceanography, you might further show the interdisciplinary nature of this science by tying it

in with the meteorology discussed in "Probing the Atmosphere." Meteorology is closely involved in various aspects of oceanography, because air masses and water masses can affect each other in many ways. The meteorologist is concerned with heat transport by water masses. The oceanographer needs to understand the nature and extent of the effects of moving air masses on the surface currents and temperatures of the oceans.

This section also provides a good opportunity to discuss the role of mathematics in science. In oceanographic research, mathematics provides a means to describe and to analyze the vast and increasing quantities of data being provided. Computers and data-processing systems are already aboard ships.

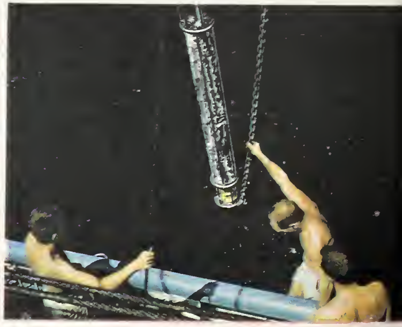
The modern oceanographer, like most other scientists, is dependent on instruments and equipment. These instruments include simple as well as very intricate equipment. Descriptions of some of the oceanographers' instruments follow:

Dredge: A heavy metal frame to which a net is fastened. The lower edge of the frame digs into the sea bottom, loosens plant and animal life there, and passes it back into the net.

An explosive charge sets off earthquake-type waves that are picked up on sensitive instruments aboard ship. The measurements made from these artificial earthquakes will indicate how thick the layer of sediment on the ocean floor is.

From 900 feet in the ocean comes a bathythermograph, or B.T. This instrument scratches a temperature-depth record on a chemically treated glass plate. The plate is then placed in a viewer so that scientists can read it. This is one of the most useful and familiar of oceanic instruments.

The current meter being raised on to the ship gives scientists measurements of ocean currents at various depths. Measurements of both speed and direction can be made.



Wind speed and direction are recorded by instruments mounted on buoys. This is a transmitting buoy being set into position.

This is a box corer. It is used to obtain undisturbed samples of sediment.

Look what the net brought up — a man-of-war! This jellyfish has tentacles which are able to sting and entangle any small animals they touch.

Below decks, a scientist studies a squid, which he will take back to his laboratory on shore.

Stand clear! Wave tower going up.

Plankton townet: A cone-shaped cloth bag, whose mouth is held open by a metal ring. A metal can or glass jar is attached to the small end. The bag is towed at slow speed to catch various plankton in the can or jar.

Nansen bottles: These are named for the Norwegian explorer-oceanographer, Fridtjof Nansen, who invented the bottle. It is a cylindrical metal bottle open at both ends. There are caps or seals at both ends that can be closed automatically. The bottle is attached to a wire and submerged. Water flows freely through the bottle until it has reached the desired depth. A weight is dropped down the wire to trip a device that closes the top and bottom of the bottle, trapping the water within it. When this occurs, the bottle turns over, and this movement fixes the mercury column in a thermometer fastened to the outside of the bottle. The thermometer records the temperature of the water at the exact moment when the bottle is turned over. In this manner, the temperature of the ocean at any depth may be measured. Usually a number of such bottles are used at the same time at various depths. Each bottle, as it closes, releases a second weight, which drops to the bottle below, repeating the operation.

Bathythermograph: This instrument constructs hourly vertical temperature profiles of the upper layers of ocean water. It is a bullet-shaped instrument that traces the curve of temperature as a function of depth on a smoked-glass slide.

Corer: This is a long pipe, which can be driven into the bottom sediment, usually with a great weight. When the pipe is extracted, it brings back with it a sample of penetrated sediment. Such corers can penetrate the sediment up to 60 feet below the bottom. Because sediment is deposited so slowly, scientists have an opportunity to examine sediment that was laid down millions of years ago, buried deep in the core sample. Careful examination of these samples has revealed to scientists much about what the ocean and the earth were like in the past.

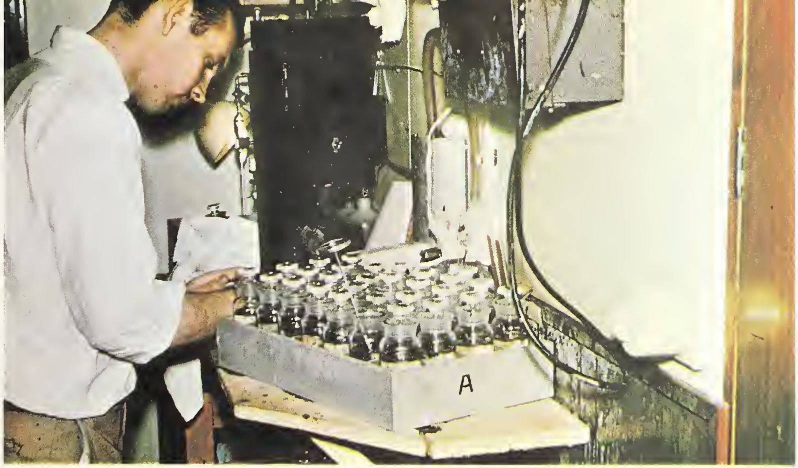
Echo-sounder: The echo-sounder "sees" the ocean bottom with pulses of sound. It traces the topographical variations of the ocean floor and tells its depth.

Seismic soundings measure the real bottom, under the sediment on the ocean floor. They also tell the composition of the ocean floor. They differ from echo soundings in that instead of mak-

Here's the finished tower. Two scientists are seen making adjustments. Data about waves are radioed from this tower back to shore.

Man is curious. He needs to see for himself the ocean's ways and life. The cubmarine is a one-man submarine that enables him to explore the deep.

Every ship doing research at sea is backed by a land laboratory. At the laboratory of the Woods Hole Oceanographic Institution, a scientist runs a series of tests on samples collected at sea.



Another scientist uses a salinometer to find how much salt there is in each sample of ocean water.

Another scientist studies pictures taken of the ocean's bottom so that he can write a report of his findings.

Getting ready for the next voyage means placing letters in drift bottles. Each note asks that the finder mail back the note. The bottles will be thrown into the ocean. Scientists can trace oceanic currents by learning where these bottles are found.

ing a quick trip to the ocean floor and back, the seismic waves travel to the ocean floor, then move along the bottom's underlying layers. To do this, two ships are needed. From one ship, a depth charge is set off, which creates earthquake waves in the sea bed. A hydrophone, which is like an underwater microphone, 10 to 25 miles away on the second ship, picks up the echoes of these waves, first from the top of the sediment layer, then from the rock layer's bottom. The second echoes give the measure of the real bottom, while the difference in arrival time of these waves gives the thickness of the layer of sediment.

Underwater cameras: A common 35 mm. camera protected against pressure by a strong aluminum vessel is provided with a strong light and a trigger to flash the light and wind the film when it makes contact with the bottom. Stereoscopic time-lapse cameras loaded with color film are used to obtain almost continuous three-dimensional views of the terrain over which a ship is drifting. Underwater cameras are also used with bottom-sampling devices to photograph marine life.

Drift bottles: These bottles are thrown into the sea to trace oceanic currents. They contain notes requesting the finders to mail them back to those who set them adrift. Here you might want to make an analogy to the radiosonde balloon discussed in "Probing the Atmosphere."

Oceanographic cruises are divided into four major types: research, survey, monitoring, and exploration.

Research: The goal of these cruises is better understanding of the operation of natural physical and biological laws and forces in the oceans.

Survey: These cruises prepare precise charts of shorelines, depths, shoals, bottom contours, temperature, major currents, salinity patterns, and the structure and content of the ocean floor.

Monitoring: These cruises gather data at regular intervals from many locations. "Weather maps" of the sea, showing how the ocean changes, are drawn by measuring large areas of the ocean at the same time or at regular intervals of months or weeks.

Even airplanes are used by oceanographers. Cameras mounted on airplanes take pictures of changes along a shoreline caused by storms and other forces. Movies record the development of clouds. Special thermometers measure the surface temperature of the ocean and also locate oceanic currents.

Ships, instruments, and computers need people to man, invent, and operate them. Oceanography presents young men and women with an exciting opportunity to explore the last unknown frontier on earth — the oceans.

Using What You Have Learned

1. Besides the vessels described in this chapter, there are others that have been built for exploring beneath the sea. Prepare a report on the small two-man subs that are now being used. Find out about *Flip*, the research vessel that can stand on end.

2. Make a model of the ocean showing the different kinds of living things at different depths. Cutouts of various kinds could be hung by threads at the proper depths.

3. The earth is slowly warming up. As it warms up, some of the snow and ice in the polar regions melts. Tell about some of the effects on ocean and land areas caused by melting.

TEACHING SUGGESTIONS
(p. 329)

Background: Possible answers to question 3 under *Using What You Have Learned* include:

As the ice and snow of the polar regions melt, the ocean levels will gradually rise. The rising water will change the shape of continents' coastlines. Many of the coastal cities of the world will be flooded.

There is another aspect to consider, however. Much of the Arctic ice is floating on the ocean. When this ice melts, the water level will remain the same or even fall.

Try this experiment. Put an ice cube in a glass, then carefully fill the glass to its brim. When the ice has melted, examine the water level.

- *Has it changed?*
- *Has it gone down?*
- *Did the glass overflow?* (The glass does not overflow, because the ice occupies more volume than the same weight of water would. When it melts, the total volume decreases.)

TEACHING SUGGESTIONS
(pp. 330–333)

LESSON: How do oceans change?

Background: There are four kinds of ocean currents: surface currents; those under the surface in the opposite direction to the first; upward (upwelling) currents; and downward currents, or downflows. The chief causes of surface currents are the trade winds, which flow in the opposite direction to the eastward spinning of the earth. The main currents caused by these winds are the westward-flowing equatorial currents, one north and the other south of the equator. The positions of the continents of North and South America produce a clockwise motion of the currents in the North Atlantic and a counterclockwise motion in the South Atlantic. This pattern is illustrated on page 333 of the text. A similar pattern exists in the Pacific Ocean.

Learnings to Be Developed:

Temperature and salinity of the ocean vary widely from one area to another; they also vary over a period of time.

Ocean life responds to these variations.

Density of ocean water varies in accordance with the amount and kind of elements dissolved in it.

The Ocean Environment

Life exists in great abundance and in great variety in the oceans. The key to important ideas about these living things is the environment in which they live. We must study their environment to explain how the variety of ocean life developed and how it continues to change.

You might think that the ocean environment is the same all over. Or you might expect the ocean to be warmer in the south and colder in the north, or clear in some places and murky in others.

If you have been to the seashore, you know that even these simple statements are not quite true. Cape Cod, Massachusetts, is in the northeastern part of the United States. Some waters on the Cape are warm enough for summer bathing, while others, only 50 miles away, are much too cold. Even in the same bathing area you can find places that are warmer than others. Water temperature is *not* uniform even in a small part of the ocean.

Have you ever gone swimming in water that was very easy to float on? The sea is salty, but it is saltier in some parts than in others. In *very* salty water, as in the Great Salt Lake in Utah, it is impossible to sink.

Have you seen signs of how life changes in the sea? A few years ago, blue sharks were seen off the coast of New Jersey. This shark usually makes its home in warm, tropical waters. The waters near New Jersey are cold. These sharks seemed to have traveled northward. Every now and then fish move to a different area of the ocean. Part of the reason is that their old environment has changed. Since they cannot survive there, they must move. These observations give us clues to some key ideas of oceanography:

1. The ocean environment is not uniform; it is really many different kinds of environments.
2. The ocean environment is constantly changing.
3. Ocean life is sensitive to even slight changes in environment.

The Changing Oceans

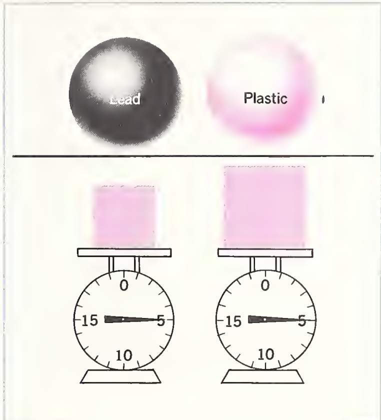
You know that the land is continuously changing. Wind and water cause it to change. Oceans, too, are continuously changing. Scientists study these changes to find out more about the oceans.

Traveling in oceanographic ships, scientists take samples of the water. Sci-

entists record the depths at which the samples are taken. They collect specimens of living things and of the sounds they make. They drop current detectors overboard. These are plastic discs on long, slender tubes that ride along the underwater currents. Each has information on it about where it was dropped. Somewhere, sometime, many of these are found. The finder writes down where he picked up the detector and sends it to the oceanographic institute. Information can be pieced together in this way about how currents are running.

In laboratories on the ships, scientists analyze the samples they have taken. First, they want to know about the watery environment in which an animal lives. How would you go about describing a sample of water?

One way scientists can describe water is to tell what its **density** is. What does density mean? Scientists often define something by telling how two things are related. The two things related here are the mass of an object and the space that it takes up. Density is the relation between these two things. A heavy object that does not take up much space is denser than a light object that takes up the same space. A lead ball is denser than a plastic one of the same volume. If two objects weigh the same



Which is denser, the lead ball or the plastic ball? Which is denser, the large box or the small box? How can you tell?

but one takes up less space, then that one is denser than the other. Which is denser, a pound of lead or a pound of plastic?

The density of sea water is not the same all over. Density varies with the elements that are dissolved in the water. Two of these elements, sodium and chlorine, make up our table salt. Other chemical elements that are abundant in the sea are potassium, magnesium, bromine, and calcium. In fact, the same elements that are found on land are also found in the sea. Even silver and gold are found in the sea.

Salts—potassium chloride and sodium chloride—cause the oceans' salinity.

Ocean currents are created by convection.

Developing the Lesson: Begin by having the children read the introductory section.

It is impossible to sink in the Great Salt Lake because the weight of a volume of the water in that lake equal to the volume of your body equals the weight of your body. The water is as heavy as you are, and so you cannot sink.

Ask the children to define "density" in their own words. Refer to the picture at the top of the page. The lead ball is denser; the small box is denser. A pound of lead is denser than a pound of plastic.

A cubic mile of ocean water contains the following amounts of elements: salt—117,000,000 tons; magnesium—6,000,000 tons; potash—300,000 tons; silver—15 tons; uranium—70 tons.

NaCl is sodium chloride, or common table salt.

- *How is the salinity of the ocean related to its density?* (The greater the salinity, the greater the density.)

You can illustrate the relationship between salinity and density with this experiment. Put a beaker on a scale, weigh it, and then fill the beaker with water. Record the weight of the water (subtract the weight of the beaker from the total weight). Make a red line with a crayon to indicate the water level. Then add several tablespoons of salt to the water and stir to dissolve it. Record the new weight.

- *Does our water weigh more now?* (It will.)
- *Does it occupy any more space? (Yes.)*
- *Is it any more saline?* (Yes.)
- *Is it denser?* (Yes.)

If the children wonder where the salt went, explain briefly that it is in solution, *between* the water molecules, so the water increases in volume as well as in weight.

Piaget reports in connection with a dissolution task, that the ten-year-old thinks that the water level in a glass will rise when salt is added, but will sink after the salt has been dissolved.

A scientist tests the salinity of ocean water.

Density of water varies with the kinds of elements dissolved in it, as well as with the amount packed into the same space.

Most of the elements in the sea are found as chemical compounds known as salts. Potassium and chlorine combine to make potassium chloride. What elements combine to make NaCl?

Density, then, depends mostly upon the salts dissolved in the water. Scientists are interested in the saltiness of the water. The saltiness of water is called its **salinity** (suh-LIN-uh-tee). Salinity is measured by instruments like the one above.

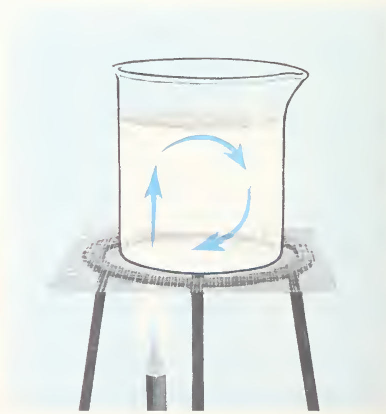
Where would you expect to find the salinity of ocean water the greatest? Samples of water have been taken from different depths. The salinity of the samples has been determined. Scientists have found waters of high salinity at various depths of the ocean.

Ocean Currents

Water in the oceans is constantly in motion. Scientists have found that much ocean water moves in strong ocean streams called currents.

To explain these streams of water in the ocean, we must find out what causes water to move. The process causing movement is **convection** (kun-VEK-shun). Heated matter is pushed by

Explain what is happening in the water in the diagram below.



colder matter. When you put a pan of water over a fire, the water at the bottom of the pan heats up first. As the molecules in the water become heated, they move about faster and also move farther apart. This water becomes less dense. Colder, heavier water is pulled down by gravity and crowds out the warmer water. There is a constant downward and upward movement of water until all of it is boiling.

Now let us see what happens in the ocean. The sun warms the ocean, but it does so unevenly: Tropical waters receive a great deal of heat from the direct rays of the sun. Shallow waters heat up more quickly than deep waters. The sun shines on some parts of the ocean, whereas clouds prevent the sun from shining on other parts. Winds carrying warm air heat some parts, while others are chilled by cold winds.

As waters become heated and less dense, they are crowded out by cooler, denser waters, pulled down by the force of gravity. In this exchange, a current is created. Winds pick up the current and push it along. Large currents like the Gulf Stream are pushed along by westerly winds.

Can you trace the paths of the currents shown in the drawing below?

Ocean Currents and Salinity

Waters in the ocean, then, are not still. They do not rest in layers with the saltiest at the bottom. Ocean currents carry the dissolved salts along with them.

Scientists have made the following observations about the saltiness of ocean waters:

1. Waters near mouths of rivers tend to be high in salt content.
2. Tropical waters tend to be high in salt content.
3. Waters near the North and South Poles are saltier in winter than in summer.
4. The kinds of salts in the water are not the same in all parts of the sea.

Demonstrate the principle that as *water is warmed, it becomes lighter and rises. It is displaced by colder water.* Fill a quart bottle with warm water, add a small amount of food coloring, and mix. Fill a second quart bottle with cold water. Cover the mouth of the first bottle with a file card. Invert the first bottle over the second. Pull out the card from between the bottles. Tell the children to watch the direction in which the water flows. Repeat the experiment, reversing the positions of the bottles.

- *In which direction is there a greater flow of water? Why?*

Call attention to the importance of the currents that supply the west coasts of North and South America with rich nutrients and plankton, used as food by fish.

ADDITIONAL ACTIVITIES:

Try this experiment. Fill two beakers with water, add several tablespoons of salt to each, and stir to dissolve the salt. Weigh the beakers and record their weights. (They should be the same.) Cover one beaker to prevent evaporation. Let the other beaker remain in the open. After several days, pour 1 pint of water from the first beaker into a container and weigh it. Repeat this procedure with water from the uncovered beaker.

TEACHING SUGGESTIONS
(pp. 334–338)

LESSON: How does the ocean environment change?

Background: Life originated in the oceans several billion years ago. There the first primitive living things were formed from long chains of complex molecules. There life developed toward greater size and diversity. Eventually, life invaded the land and adapted to it. In the oceans, life continued to grow more complex and more responsive to the environment.

Learnings to Be Developed:

Ocean life changes when the oceans change.

All life began in the oceans.

Attempts to find "living fossils"—primitive forms of life—at the changeless ocean depths were fruitless.

The forms of creatures found in the depths illustrate how life adapts to an environment.

Life began near the surface of the ocean.

Developing the Lesson: Have the children read "A Changing Environment and Changing Life." To review the section, ask these questions:

Scientists have found these facts about salinity by analyzing samples of water. But how do they explain these facts? Let us start by finding out where the minerals in the waters come from.

As rain water flows over the land, it picks up salt and other minerals. Water, with these salts and minerals, flows into rivers and finally into the ocean. Water is always evaporating from the ocean, but the minerals do not evaporate; they remain in the sea. The amount of minerals in the ocean keeps increasing. Some scientists have tried to tell how old the earth is by the amount of salt or minerals in the ocean. Can you explain how they might do this?

Minerals are added to the ocean in another way. When a weak part of the earth's crust breaks down, some hot liquids and gases from deep inside the earth escape from a volcano. When volcanoes erupt under the sea, minerals from inside the earth are released into the water. When volcanoes erupt on land, there will be minerals on the surface to be washed into the sea.

In tropical regions, water evaporates very quickly, leaving more salts in the remaining waters. In polar regions, the surface waters freeze in winter. As they freeze, the salts drop to the waters beneath. In the winter, then, polar waters are saltier than they are in summer. In the summer, the ice melts, freeing water that is low in salinity. This water mixes with waters high in salts. The waters become less salty.

A Changing Environment and Changing Life

We have seen how the ocean provides many different environments for living things. There are differences in temperature, density, chemical makeup, and movement of the waters.

Ocean life responds to change, but there is a limit to the changes to which a living thing can adjust. A plant or animal can only stand a certain range of temperature. If a polar bear is put into tropical waters, it will die. Tropical fish cannot stand the Arctic waters.

The chemical makeup of water must also be of a certain kind for a plant or animal. You probably know that goldfish will die if you put them in water right out of the faucet. Most of our drinking water has too much chlorine in it for goldfish.

One year scientists noted a sharp drop in the mineral phosphate in the water of the English Channel. Shortly after this, they noticed there was much less plant life in the water and fewer young fish. In a while, there were no more her-

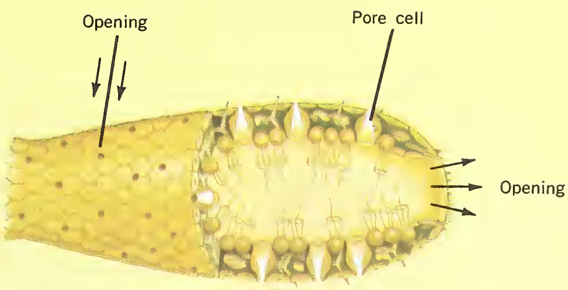
ring. Herring had previously been plentiful enough so that a whole fishing industry depended on them. A change in that section of the ocean environment brought a drastic change in the life found there.

Menhaden, a member of the herring family, are important for the oil they contain. Sometimes as much as 60 gallons of oil is obtained from a ton of fish. At other times, considerably less oil is obtained from the same amount of menhaden caught in the same area. From what you have learned, can you give a possible reason for this difference in oil content?

Past Life in the Oceans

In the oceans today, as on the land, we can find very simple and very complex forms of life. Can you think of some simple forms of ocean life you have already studied? Name some land animals that resemble these forms of ocean life.

Study the pictures below and on page 336. Here you find the body plans of various animals that live in the sea. You can find examples of how specialized equipment developed. How does the sponge take in food? What equipment does the jellyfish have for food-getting and protection? Study the body plan of the clam. What systems can you identify?



SPONGE

- *How do the oceans vary?* (Paragraph 1.)
- *Can we generalize from the polar bear and tropical fish to all life?* (Yes. All ocean and land life can exist only within limited ranges of temperature.)

Background: The mineral phosphate was essential to life, just as small amounts of iodine are essential for human life. When the mineral phosphate disappeared, the sea life moved away from the English Channel.

The amount of oil in menhaden depends on the presence of the chemicals that make up the oil (or chemicals that support the oil-manufacturing process, though they may not be part of the oil itself). When one of the chemicals is in short supply or absent, the amount of oil is correspondingly reduced.

After the pupils have read "Past Life in the Oceans," ask:

- *Was it logical for scientists to think they might discover living fossils at the ocean bottom? Why?*
- *Were they successful? Why not?*

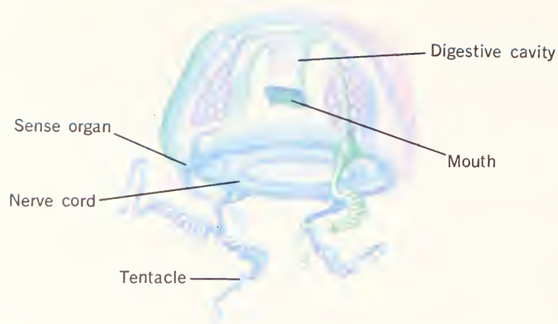
Although scientists never succeeded in finding the earliest

forms of life, they did, in the 1940's, find in the Indian Ocean the fish *Latemeria,* a member of the order Coelacanthini, which had been supposed to be extinct for 60,000,000 years. It was a living fossil.

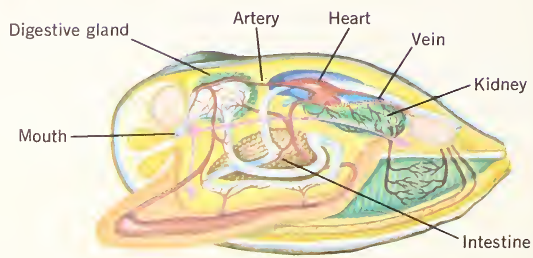
- *Why did life begin in the ocean shallows rather than in its depths?* (The early forms of life were plants, and depended on sunlight for energy. The sunlight did not penetrate the depths of the ocean.)

Background: The squid's body shape is adapted to great pressures of the depths. Luminescent squids are mostly deep-sea forms that live in darkness. They have photogenic cells, which produce light, reflector cells, and a layer of pigment to screen their internal tissues from the light. Some squids protect themselves as some octopuses do; they squirt out a jet of inky fluid—an oceanic smoke screen—and escape in the darkness.

Blind fish find their way by using long, sensitive feelers. Also, they have a very highly developed sense of smell, and are very sensitive to currents and temperatures. Such blind fish are found at great ocean depths, where the lack of light makes eyes useless.



JELLYFISH



CLAM

About one hundred years ago, some scientists tried to learn more about the origins of life. They thought that the first animals lived in the sea. Might some of these kinds of animals still exist at the bottom of the sea? Living things have changed over millions of years, but perhaps in the depths of the ocean there might still be found the same animals.

In the depths, conditions have remained much the same for millions of years. No sunlight has ever shone through. In the depths, the temperature is the same at the poles as at the equator. The seasons are the same the year around. There are no winds, no waves, and no currents. The scientists reasoned that in such an unchanging environment, life would not change. They thought that if life had begun in the lowest depths of the sea, then some ancient forms would still exist there.

In 1872, the British launched the *Challenger,* a ship equipped with laboratories and scientists. She traveled the oceans for four years, and her staff made thousands of observations. They fished strange fossils out of the sea. The fossils had living relatives familiar to the scientists. The scientists searched for **trilobites** (TRY-luh-byts). We know such creatures once existed, for there are fossil remains, but no trilobites were found. Scientists analyzed the slimy ooze at the bottom of the deep, but they did not find any living fossils.

Today, scientists believe that life did not begin in the lowest depths of the sea. There are squid and fish living there today, but these creatures have gone down to the lower depths from higher levels. While they are like their relatives living above, their body structures have changed in some ways. The changes have made survival possible in the depths. The squid and some fish have ways of lighting up the dark. The fish are small, but have huge mouths: they do not have large bodies to feed but have a lot of mouth to catch food with. Some fish are blind but have very long feelers so that they can find their way. These specialized parts enable animals to adapt to life in the depths of the oceans.

Trilobites lived about 500 million years ago. They disappeared about 200 million years ago.

How are squids adapted to their environment? How do they protect themselves?

How do blind fish find their way? Where are they usually found?

- *What remarkable thing is true about the salty elements in the blood of reptiles, birds and mammals?* (Their proportions are close to those found in the ocean.)
- *What does this imply about the origin of land life?* (Land life began in the oceans and in coming ashore brought a part of the ocean with it.)

○ **ADDITIONAL ACTIVITIES:**

Wherever possible, children living at or near the seashore should be taken on field trips to see firsthand the conditions under which different kinds of marine plants and animals are able to survive and reproduce. If this is not feasible, it is possible to set up a marine aquarium with artificial sea water many miles from the ocean. Sea animals may be obtained from supply departments of marine biological laboratories. Write to Marine Biological Supply Department, Woods Hole, Mass., or to Carolina Biological Supply Company, Elon College, North Carolina.

Field trips should be carefully planned in advance, and adequate precautions should be taken to insure the safety of the children. Sneakers are usually worn, and no swimming is allowed. Plastic pails, shovels, a few nets, a seine, and

a knife are used for the collection of organisms.

Prior to the trip, discuss with the class the kinds of living things they might expect to find in each of the seashore environments. Thus, on rocky shores, broad bands of barnacles, muscles, rockweed, and snails may be identified. Elicit the hazards these organisms must be able to stand, including the terrific pounding of waves, alternating with drying out under the hot sun. Discuss possible adaptations for these conditions—for example, ability to close shells, to adhere closely to rocks, or to retain an adequate supply of water.

On sandy beaches fiddler crabs may be found. Below the sand are many kinds of mollusks, especially clams. Worms, too, are found here. Why are most creatures found below the sand? Sand offers little protection, because few plants grow on it.

Visits to the beach should be made at the lowest possible tide, to enable children to see organisms they would ordinarily not see. To assist in identifying marine plants and animals, the book entitled *Seashores* by Zim and Ingle is highly recommended for children.

More life exists at the surface of the sea than in the depths. And it is probable that life began in the surface waters. New forms of life developed; some old ones disappeared. Animals went ashore, but they carried part of the ocean with them. Reptiles, birds, and mammals have in their blood the same elements found in the oceans. Their blood contains the salty elements—sodium, potassium, calcium—in almost the same proportion that these elements are found in ocean water.

Life probably began in the ocean, but man does not yet understand all the ocean's secrets.

Using What You Have Learned

1. If you live near the ocean, you can evaporate a pint of sea water to see how much salt and other minerals it contains. You will find that there is about one tablespoon of salt and other minerals in a pint of sea water. This means there are about 3½ pounds of minerals in 100 pounds of sea water.

2. How can we get back some mineral wealth from the ocean? One way to collect the minerals is by evaporation.

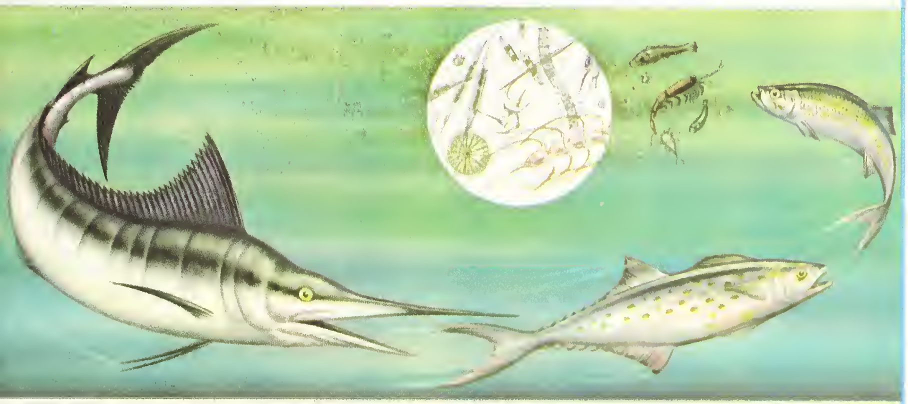
Pour a cupful of water into a shallow pan. Add three tablespoons of salt. Let it stand for several days. Observe what happens. This same general method of evaporating water is used to collect minerals from the ocean.

3. Evaporation was used to get salt long ago in Greece and Egypt. It is still used today in Iran and California. Prepare a special report on how ancient and modern methods differ.

4. Chemical change is another way of collecting some minerals from the ocean. Get some limewater and blow into it. The carbon dioxide from your breath combines with some of the lime and forms a chemical compound. This compound will not dissolve in water. If the water is left standing, the compound will settle in the same way that starch settles in water.

The Balance of Life in the Oceans

The swordfish eats the mackerel, which eats the herring, which eats tiny water animals. What do the tiny water animals eat? They eat plants that float on the surface of the sea. These plants are so small that there are thousands of them in one teaspoonful. Without these tiny plants, nothing could live in the ocean. Big sea animals depend upon smaller sea animals for food. These smaller sea animals depend upon still smaller ones, and the smallest of all depend upon plants. As you can see, no one living animal can exist by itself.



Trace the cycle of life. How is a balance of life maintained?

Plankton

The tiny green plants of the ocean and certain small animals that feed on them are called **plankton** (PLANK-tun). Plankton plants are the basic food of the sea. Each plant is so small that it can be seen only with a microscope.

Plankton is from an ancient Greek word meaning "wandering." Plankton wanders, or drifts, with the currents.

Most plankton plants are **diatoms** (DY-uh-tumz). A diatom is a one-celled green plant. Under a microscope, the diatom cell looks like a little glass

TEACHING SUGGESTIONS
(pp. 339–344)

● **LESSON:** What is the balance of life in the ocean? How can ocean life be used by man?

Learnings to Be Developed:

All life in the ocean depends ultimately on plankton.

Plankton can also be used as food for human beings.

Man's methods of farming the oceans are less efficient than his methods of farming the land; oyster farming is an exception, however.

Developing the Lesson: Have the pupils read the introduction. Then point to the picture and say:

- *Read the first paragraph again. Do you see the swordfish? The mackerel? The herring?*
- *Does the picture show a true cycle?*
- *Do the tiny animals in the picture feed upon the shark?* (No, they do not.)
- *Then how do they feed? What helps them grow?* (They feed on plankton.)

Have the class read the next section to see how the plankton support all the life in the oceans. Then ask:

- *Why were the plants named* plankton?

Have your pupils look at the picture on page 340. The greenish areas within the diatoms contain the chlorophyll.

- *Can you tell why plankton—diatoms—needn't feed on yet smaller forms of life?* (The diatoms are plants, not animals, and manufacture their own food out of water, carbon dioxide, and minerals in the water. Sunlight furnishes the energy, and chlorophyll affects the transformation.)
- *What conditions are best for growing plankton?*
- *If 256 diatoms can come from one diatom in one day, how many would there be at the end of the second day—16 divisions?* (256 × 256 = 65,536 diatoms.)

Have the children read "Food from the Sea."

- *Why do we not use plankton for food?*
- *Can you see from what we have read and from our calculations how the difficulties might be overcome?* (If plankton were grown under ideal conditions, in protected, restricted areas such as tanks, the amount of

These diatoms are greatly magnified. They come in many sizes and shapes.

These are diatoms as seen under a microscope. Do you see any chlorophyll within the cells?

box made of two parts. The two parts fit neatly into one another. The living part of the cell, which contains chlorophyll, is in between the two parts. There is a tiny slit in the glasslike box. Through this slit sea water enters the living part of the cell. Sea water contains the carbon dioxide and mineral nutrients that the cell needs to make food. It also contains the oxygen that all living things need. Thus, these plants get materials that they need directly from the water in which they float.

Plankton plants grow best where the ocean water contains the minerals they need. These plants grow best in cool waters. They can grow only as far down as light can reach—about 400 feet. Can you explain why? Warm tropical waters do not contain much plankton. That is why these waters are so clear and blue. It is plankton that clouds the northern waters and makes them look so dark.

Diatoms reproduce in a simple way. Each diatom divides to form two cells. All one-celled plants and animals reproduce in this way.

Diatoms can reproduce very rapidly. Under favorable conditions diatoms may divide as often as eight times in twenty-four hours. At this rate, you could begin with one diatom and have 256 the next day if they all lived.

What happens to plant plankton affects the whole ocean. Without plankton no life could exist in the sea. There are sea animals that eat other sea animals that eat other sea animals. But always at the beginning of the food chain there is the green plant, the diatom of the sea. Even the microscopic animal plankton must get their food from these tiny, one-celled green plants.

Food from the Sea

Plankton can be made into food for people. Plankton can be pressed together and dried. The result is a paste that is very high in food value. It is 50 per cent protein and contains every nu-

trient that man needs. However, people who have eaten plankton do not like it. Furthermore, harvesting plankton requires a great deal of time.

Man can obtain fish more easily than he can obtain plankton. For example, a group of fishermen caught over 58 tons of herring in 100 hours. To collect that much plankton, man would have to strain almost 58 *million* tons of sea water. Some scientists believe we should let fish use the plankton for food. Then we can use the fish for food. But other scientists, especially in Japan and Thailand, are working on using plankton as a direct source of food. Scientists believe that plankton may be used for food on space stations.

Plankton plants grow not only in the ocean but also in fresh-water lakes. They can be grown in tanks, too. All you need to grow them is some of the plants, sunlight, water, and minerals.

These plants may also be used for fuel. When dried, they burn with a slow, hot flame—like coal. It was from living things like these that petroleum was formed millions of years ago.

Seaweed

Seaweed are rather large plants that grow in the sea. They are closely related to some of the plankton plants. They are called algae. The seaweed algae are many-celled plants. Some of them grow to be very large. They are quite different from large land plants. Land plants need roots and stems to get water and minerals. Seaweed plants live in water and absorb minerals along with water through all their parts. Food can be made by all parts.

Most seaweed plants live at a depth of about 10 to 20 feet. They are supported by the water, so they do not need strong stems. When seaweed plants are out of the water, they sprawl all over the ground. Can you tell why?

Seaweed do not have roots; they have **holdfasts.** Holdfasts fasten to rocks or shells on the bottom of the sea.

The photomicrograph shows mixed plankton containing plants and various kinds of small animals. Find out what the animals are.

plankton possible is almost unlimited. To drive this point home, ask, "At the end of three days, how many diatoms might we have from the original one?" The answer is 65,536 × 256 = 16,776,216 diatoms.)

- *What other use of plankton is possible?*

Have the children read the section on seaweed.

- *How are seaweed algae different from plankton?* (They are many-celled, not single-celled, organisms.)
- *How are they the same?* (They, like plankton plants, can make their own food.)

Seaweed sprawls on the ground because, being supported by the water the plants never develop rigid stems such as land plants have.

Point to the picture on page 342.

- *Where are the holdfasts of the seaweed?* (They are the yellowish branches at the bottom of the plant.)
- *What do holdfasts do?* (They anchor the seaweed in place.)
- *What uses has man found for the iodine in seaweed?* (Man uses iodine in medicine; the iodine in the medicine cabinet is a 3 to 7 per cent concentration of iodine in ethyl alcohol. Some iodine is necessary in man's diet to prevent goiter.)
- *Do scientists know all the species of seaweed that exist?*

Have the children read "Farming the Sea." Then ask them:

- *What do land farmers do that we might do—but do not do—to make farms in the sea?*

Seaweed vary in color. Those that grow near the surface of the water are green. Farther down, seaweed are brown and red. These seaweed have chlorophyll too, but their green color is hidden by the brown and red coloring. Because of their coloring, they only need the small amount of light that reaches farther down into the water.

Seaweed is used in many ways. If you have ever felt seaweed just as it comes out of the water, you know it is slippery. This is due to a gelatin-like substance called agar. In the laboratory, bacteria are grown on agar. Agar is also used in making jelly, mayonnaise, and ice cream.

Seaweed is also rich in iodine. How does man use iodine? Meal can be made from dried seaweed and fed to animals.

Some scientists suggest that seaweed could be a fine source of vitamins and minerals for people in areas of the world where food is scarce. There are 836 tons of water in 1,000 tons of seaweed. What problems does this present in using seaweed as food?

If you want to be a scientist who does research on seaweed, there is much opportunity. For example, there is still work to do in identifying the different kinds of seaweed. Does a newly found specimen belong to a new species or to one that has been identified? Does it vary from known species because of the water in which it grows? A big job remains to be done in the identification and classification of seaweed before much more can be learned about it.

The holdfasts fasten the seaweed to one spot.

Farming the Seas

We do not know all the kinds of sea animals or how we might use them. We do not know all the good fishing grounds. Over three quarters of the world's fish are caught in just two fishing grounds—one in the North Atlantic and one in the North Pacific.

A land farmer fertilizes his soil, pulls weeds, sprays for insect pests, and uses carefully prepared seeds. Man does not

actually farm the sea as the land farmer farms his land. He does not remove undesirable animals, fertilize, crossbreed, or restock the sea as he sometimes restocks streams or lakes from fish hatcheries. Fishing today can be compared to hunting animals for food in pioneer days, when men took what they could find. The best fishing grounds are where currents bring water rich in nutrients up to the surface.

Just suppose new ways were developed for catching fish—ways by which larger numbers of fish could be caught than by the old methods of hooks or nets. Suppose all the bays around the shores were made into fish farms. Suppose scientists fertilized waters so that they produced more food for fish. And suppose scientists discovered ways of selecting fish for breeding purposes or ways of destroying animals that harm valuable fish. The sea might then become a much more valuable source of food.

Farming the seas is called **aquaculture** (AK-wuh-kul-cher).

Oyster Farming

One kind of sea farming that man has tried is oyster farming. Oysters live in the shallow, warm waters of the oceans. They are often harvested wild by oystermen, but more and more they are being

Some countries, such as Russia, use modern scientific methods to aid in fishing. This Russian underwater automatic camera tells not only where fish are in large numbers but also how many of them there are. Helicopters are also used to assist fishing fleets in spotting schools of mackerel and other fish.

• *Why do you suppose we are not doing those things today?* (There are at least five major reasons: 1. We do not know enough about the oceans' currents, composition, and geography to be able to control them as we do the land's. 2. We do not know the relationship between ocean composition and life in the ocean. 3. Little research has been done on selective breeding of ocean life. 4. The technology of aquaculture—the machines, the control equipment, the harvesting devices—has not been developed. 5. We do not know how man would adapt to life on the ocean farms.)

When the children have finished reading "Oyster Farming," discuss another example of sea farming—the raising of clams. Then have the children report on the sea farming of clams, finding out what means the farmer uses to select his clams, how he plants them, how he cultivates them, and how he harvests them.

grown in carefully prepared oyster beds. With special care, the oyster farmer can produce more and better oysters than he produces now.

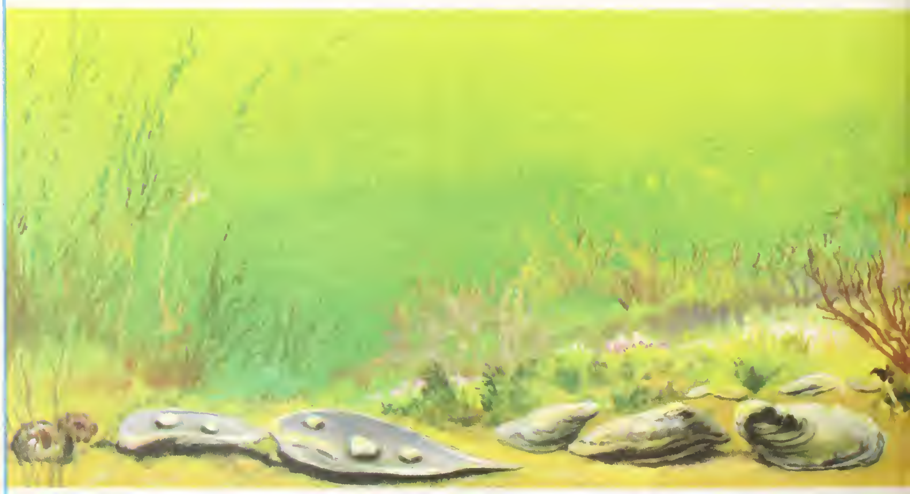
The oyster farmer cleans a small part of the bottom of a bay where the water is not polluted. Then he places oyster shells on the bottom.

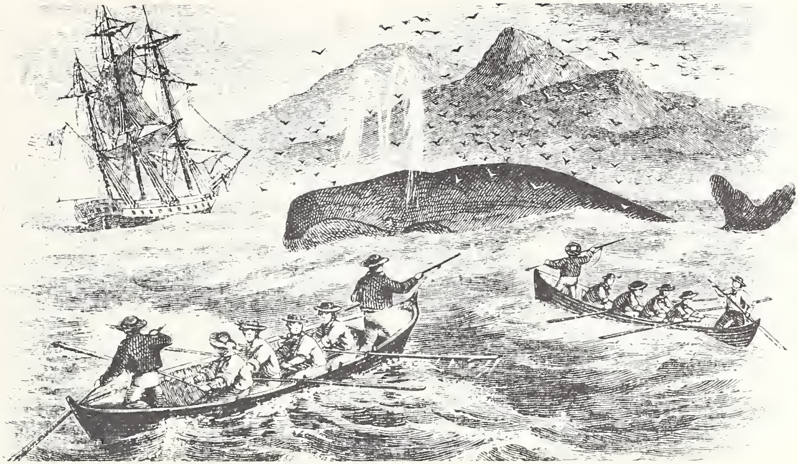
The female oyster produces her eggs in the summer. She lays from 15 million to 114 million eggs at a time, and she may produce several batches a season.

So many eggs are produced by the female that you might think the seas would soon be thick with oysters. Since many of the eggs are not fertilized, this does not happen. The fertilized eggs hatch into tiny **larvae.** (*Larvae* is the plural of the word *larva.*) Many larvae of the oyster are eaten by hungry fish. Fifteen days after hatching, the larvae drop to the bottom of the sea. They fasten themselves to the shells placed there by the farmer. They fasten themselves so tightly that most sea creatures cannot pull them off. When settled on the bottom, the larvae grow shells around themselves. Then they are safer from enemies.

After a few months, the oyster farmer moves the oysters to another spot where they will have more room and food to grow. It takes from three to four years for an oyster to become fully grown.

Oysters eat plankton, which is rich in iron and iodine. Oysters are also high in vitamins and proteins. Therefore, oysters are an excellent food for man.





The Great Mammals of the Sea

"Thar she blows!" called the lookout on the sailing ship. He had sighted a whale. The chase was on! In the nineteenth century, great sailing fleets roamed the Arctic and Antarctic Oceans looking for whales and their valuable oil.

Whales are not fish; they are mammals. Dogs, cows, bears, and humans are mammals. Most mammals are land animals. It is believed that mammals developed on land millions of years ago. Why, then, do whales live in the sea?

Whales also developed as land animals. Scientists have found fossils that prove that whales once lived on land. Judging by the tremendous teeth and jaws of fossil whales, scientists believe land whales must have been powerful beasts.

Why did whales leave the land? One hypothesis is that they became too large for land travel. Another is that long ago whales may have discovered the great number of fish at the edge of the sea. No one is certain.

We know about some of the ways in which living things have changed. From time to time, living things are born that differ in some way from their parents, grandparents, or great grandparents. If this new trait helps the living thing to

TEACHING SUGGESTIONS
(pp. 345–347)

LESSON: What mammal lives in the sea?

Learnings to Be Developed: Whales are the mammals of the oceans.

Developing the Lesson: The last form of life treated in this section is the whale. Develop the section carefully, pointing out that of all forms of life in the oceans, the whale is closest to man. Some scientists suspect that one kind of whale, the dolphin, many be as intelligent as man. Its brain is fully as large and complicated as our own.

- *Why did men of the 19th century hunt whales?* (For their oil. Whale blubber could be reduced to an oil, which was burned in the lamps of that era.)
- *Are whales fish?*
- *Did whales originate in the ocean?*
- *Why did they become ocean creatures?*

Review the principles of adaption and survival of the fittest with the children. In any group of whales, some were better equipped to survive in the ocean than others. They might have had some small

advantage, such as a more efficient flipper that allowed them to swim more swiftly. Those without the flipper were caught and killed by their enemies more often than those who had it. So those with the flipper tended to survive, to breed, and to pass the flipper on to new generations, while those who lacked it tended not to survive and breed.

So with all the features of the whale. In the ruthless struggle for existence, any feature that helped survival—such as size, or speed, or color—tended to become a permanent part of the animal. Any feature that did not help tended to gradually disappear.

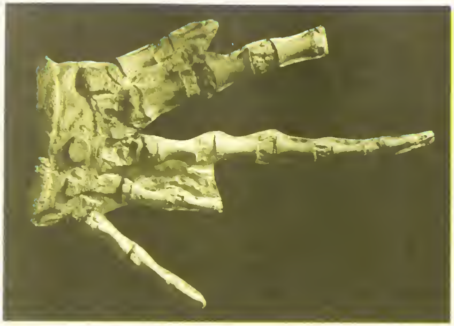
This principle applies not only to the whale, but to all life.

How did the principle work in the case of man? What advantages do we have over the life around us? (Bifocal color vision, opposed thumbs, and above all an extremely complex brain.)

How is a whale like a human being?

How is it different?

Whales have fewer young than fish because whales are mammals. Fish lay thousands of eggs, which lie unprotected on the ocean bottom. Most of the eggs die or are eaten; a few survive, develop, and



What do the bones of the whale's flipper look like? What does this tell you about the whale?

survive, living things born with this trait are more likely to live and have offspring than are those without it.

This is probably what happened to whales during a period of millions of years as their environment changed from land to sea. Some of the changes made it possible for whales to take to the water. For example, the flippers of the whale have parts that are similar to parts of the legs of land animals.

The whale is the largest animal on earth. Like other mammals, the female gives birth to live young. The eggs she produces are fertilized in her body. The fertilized egg develops into a young whale inside the female's body. After it is born, the young whale obtains milk from its mother. A whale weighs about 14,000 pounds when it is born. How much does a human baby usually weigh? Now think of a 7-ton baby! The mother whale may weigh fifteen times as much.

At six months, the young whales are ready to feed themselves. What do they eat? One kind of whale, called the whalebone whale, eats plankton and shrimp. This whale has a built-in strainer in its upper jaw which looks like a curved comb. This strainer is called the whalebone. The whale gulps huge amounts of water into its mouth and strains the water through the whalebone, keeping the plankton inside its mouth. How much plankton must a whale eat?

Since whales are mammals, they are not able to take oxygen from the water

The whale, whose skeleton you see here, has a strainer in its upper jaw.

as fish do. Whales usually swim just beneath the surface of the water. Every few minutes, whales come to the surface to breathe. As a whale comes to the surface, it blows a tremendous spout of vapor from its nostrils, which are on the top of its head. In the air, the vapor condenses and can be seen. This is the signal that whaling men look for. The spout is followed by a whistling rush of air into the nostrils. Then the whale disappears under the surface of the water.

The whale develops a layer of stringy, white fat called blubber under its skin. Blubber protects the whale from the cold water. In very cold water, this layer may be 9 inches thick. Whales that live in warm waters need less blubber. When a whale travels through warm water, some of its blubber may be used up to give the whale energy, because it is hard for the whale to find food in warm water.

One fish lays many thousands of eggs. Whales have fewer young than fish have. Why is this so? Since whales have fewer young, can you explain why catching great numbers of whales might cause serious problems? So many of some kinds of whales were caught in the past that there was a danger of certain species dying out. Because of this, an International Whaling Convention, or agreement, was made by many countries. It limited the number of whales that can be caught.

A spout of vapor means there's a whale nearby.

There are many puzzles about whales for future scientists—perhaps you—to solve. Whales need such large amounts of food that they are forced to travel great distances to get it. We still do not know what routes the whales travel to get food. Scientists have studied the contents of the stomachs of whales caught in the North Pacific. Once scientists found a mackerel in a whale's stomach—a mackerel far larger than any ever caught by Japanese fishermen in the region. Scientists have no idea where the mackerel came from.

grow into adult fish. In mammals, including whales and man, a different approach to this problem is made. The young develop within the mother's body and are nurtured by the mother after birth. The chances for survival of any individual are increased enormously. It is not necessary to breed thousands in hopes that a few will survive. In most species of whales, a normal birth consists of one baby whale.

The whale, huge as it is, is almost defenseless against man. The biological mechanisms that might compensate for man's devastation by causing whales to breed more often do not work in the short span of time—some 300 years—that man has been hunting whales.

The destruction of an entire species to light lamps and make perfume is a tragedy. The International Whaling Convention came about both through the conviction that the slaughter of the oceans' highest form of life must be brought under control, and through enlightened self-interest; man realized that when the last whale died, all the industries that depended on whales would be killed as well.

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(pp. 348–350)

LESSON: How can we use the mineral resources of the oceans?

Learnings to Be Developed: The mineral wealth of the oceans is great, and unexploited.

Developing the Lesson: When the children have finished reading the section "Mining the Sea," ask,

- *Has man been successful in mining the sea?* (No.)

Point out that mining the sea and another great problem—desalinization of sea water—are opposite sides of the same problem. Some scientists are searching for ways to extract elements from the ocean, leaving the water behind. Other scientists are searching for ways to remove the water from the ocean water, leaving the elements—especially the salts—behind.

- *Why can't we mine the nodules?* (Because they are on the ocean floor, too deep to be mined profitably. Refer to the limitations of aquaculture discussed earlier. Some of the same technological shortcomings make mining the nodules impractical at this time.)

The second picture on page 349 shows that a limited amount of

Mining the Sea

The water in the ocean tastes salty because of the minerals it contains. About three-fourths of the salt in the ocean is sodium chloride, the same salt that we use on food. The chart lists some of the mineral elements in the ocean and how we use them.

Gold and silver make up a small part of the minerals in the sea. Yet in a stretch of water 1 mile long, 1 mile wide, and 1 mile deep, there are 93 million dollars' worth of gold and 8.5 million dollars' worth of silver. So far no one has found a profitable way to get these precious elements out of sea water.

Minerals are also found on the ocean floor in the form of **nodules** (NOD-yoolz). A nodule is a lump. Nodules in the ocean are about the size of potatoes and are made of such minerals as manganese, cobalt, iron, nickel, and copper. Some estimates of the quantity of manganese in nodules run as high as 200 million tons. So far, no inexpensive way has been found to collect these nodules, but mineralogists are trying to develop a method.

Important Elements in the Ocean

Chemical	Uses
SODIUM	Table salt
MAGNESIUM	Airplane parts, printing inks, insulating materials, medicines
POTASSIUM	Medicines, dyes, fertilizers, paints
BROMINE	High-test gasoline, medicines, photographic films
CHLORINE	Table salt, bleach, disinfectant

Nodules are rich in various minerals. These nodules were found on the bottom of the ocean floor. They are very rich in manganese.

Seawater is piped into large tanks and mixed with chemicals. Minerals such as magnesium can then be separated from the water and used.

Many of the mineral resources on land are being rapidly depleted. Meanwhile our population is growing. Our need for minerals is also growing because we have invented jets, rockets, and many other machines that are made from minerals. It is important to find better ways of getting the great mineral treasures of the sea.

The Future in Oceanography

As man makes more use of the sea and its resources, the forecasting of ocean conditions will become more important. Forecasting the strength of winds over the seas will reduce transoceanic crossing times, increase passenger comfort, and reduce ship maintenance costs. Most important, it will save the lives of men.

Fish forecasting will help to find out how the surface winds affect the production of food on which fish feed and how they affect the death of young fish. Today, fish forecasting is used in haddock fishing on Lake George in New York State. Knowing how strong offshore winds are and how long they will last makes it possible to predict the size of the harvest three years ahead of time.

sea mining is possible, if first we bring the sea up onto the land.

When the children have finished the section titled, "The Future of Oceanography," review the section and then recall the present limitations of man's exploration and exploitation of the oceans. It should be clear to the children that oceanography is a young science whose impact will one day be very great.

ADDITIONAL ACTIVITIES:

Show the film entitled "The Restless Sea," obtainable from the Bell Telephone Company.

Films on mollusks, echinoderms, arthropods, sponges, and coelenterates are obtainable through Encyclopaedia Britannica Films.

"Secrets of The Underwater World," a Walt Disney Production will stimulate much discussion. An unusual film about marine life is "The Living Tide," obtainable from Dr. Roman Vishniac, Albert Einstein School of Medicine, New York City.

If you are in a coastal city, visit marine aquaria with your class. A visit to the local Museum of Natural History will also be found worthwhile.

Try hatching brine shrimp from dry eggs. When put in salt water, brine shrimp will hatch in one or two days. Let children try the effect of increasing or decreasing salinity on the viability of these organisms.

Have your class make a study of the different zones in which seashore plants and animals of different kinds may be found. Study life on a rocky shore, sandy beach, mud flat, wharf, or piling.

Find out about environmental factors, such as saltiness of water, height of the tide, amount of light, temperature of the water, amount of exposure to wave action, or dessication, which may affect the lives of animals and plants in a particular locality.

Show the film entitled "Science of The Sea," obtainable from Oceanographic Institute, Woods Hole, Mass.

Along the Seashore, by Margaret Waring Buck, is an excellent introduction to seashore life, very readable for fifth grade children.

A helicopter prepares to land on an oil rig that taps petroleum from the sea.

In certain parts of the world, the shortage of water prevents many countries from developing their industries. Fresh water is becoming increasingly important to these countries. Ways have already been found to produce fresh water from sea water, but better and cheaper methods are needed. Fresh water will be the major product that will be taken artificially from the sea in the years to come.

Scientists say that four hundred billion barrels of petroleum lie beneath the sea. As we use up the petroleum resources on the land, we shall tap the sea for oil even more than we tap the sea now.

The Challenge for You

There is so much to learn about the oceans that many kinds of scientists are needed. Each field of science lends its knowledge to the solution of the problems of the oceans.

If you were to visit an oceanographic ship, you would find marine biologists, chemists, physicists, geologists, meteorologists, botanists, and zoologists. Each scientist has special skills to use in searching for the answers to the mysteries of the oceans.

In the years to come, there will be a greater need for oceanographers. Perhaps you will want to become an explorer of the sea.

Using What You Have Learned

1. Visit a fish hatchery if you live near one. What fish are raised there? What is milt? How are the eggs and milt obtained? How are the young fish distributed? What research is being done there?

2. Make a bulletin board showing foods that we get from the sea. Use pictures of sea foods from magazines and newspapers—caviar, codfish cakes, tuna fish, etc.

3. Make a chart showing how man uses the wealth of the sea. Include such things as cod liver oil and fertilizer.

4. If you live near the shore, make a collection of sea shells. Try to find out from what sea animal each shell came. Label all the shells.

5. Look up articles on the following subjects in an encyclopedia or ask your librarian for material on them: bathysphere, William Beebe, sea horse, starfish, sand dollar, salmon, eels, coelacanth, porpoise, dolphin, seal, walrus, sea otter, ambergris. You might want to report to the class on one of these subjects.

6. Use an encyclopedia or other books to find the answers to these questions: How are the mouths of different fish suited to catching the particular food that they eat? What are some of the ways that fish have of protecting themselves from enemies?

7. Buy a whole fish at a market. Or perhaps you can catch one yourself. Explain to your class how the fish uses its fins and tail. Find the gills. Cut the fish open. Find the air bladder and explain how the fish uses it.

8. Polluted waters are destroying thousands of dollars worth of fish each year. Find out what is causing this pollution. What are government and industry doing to prevent this pollution?

To further your understanding of oceanography the following books are recommended:

Assault on the Unknown, by W. Sullivan (McGraw-Hill, 1961).

A Biography of the Sea, by R. A. Carrington (Basic Books, Inc., 1960).

Fishes, Golden Nature Guide, by H. S. Zim and H. H. Shoemaker (Golden Press, 1956).

Frontiers of the Sea, by R. D. Cowen (Doubleday, 1961).

Half Mile Down, by William Beebe (Harcourt, 1934).

A Hole in the Bottom of the Sea, by W. Bascom (Doubleday, 1961).

1001 Questions Answered About the Seashore, by N. J. Berrill and Jacquelyn (Dodd, Mead, 1957).

Seashores, Golden Nature Guide, by H. S. Zim and L. Ingle (Golden Press, 1955).

Seaweeds and Their Uses, by J. J. Chapman (Putnam, 1952).

The Sea Around Us, by Rachel Carson (Oxford University, 1961).

The Sea, Life Nature Library, by L. Engle and the Editors of Life (Time, Inc., 1961).

The Silent World, by J. Y. Cousteau (Harper, 1953).

TEACHING SUGGESTIONS
(pp. 352–353)

Background: These two pages constitute a review of the concepts and terminology introduced in this unit.

What You Have Learned: This is a summary of the entire unit, with new words in boldface type.

Checklist of Science Words: Remind the pupils that there is a *Dictionary of Science Words* on pages 358–364. They should consult this dictionary whenever they are unsure of the precise meaning of a word.

WHAT YOU KNOW ABOUT

Probing the Oceans

What You Have Learned

Oceanography is the study of the oceans and seas. In order to study the oceans, men need special devices. **Aqualungs** help men breathe while skin diving. Another device, the **bathyscaphe,** enables scientists to go much deeper into the ocean.

The density of the ocean depends mostly on the amount of salts dissolved in the water. The saltiness of the water is called its **salinity.**

Scientists have found that the ocean environment is not uniform; it is a variety of environments. It is constantly changing. Ocean life is sensitive to even slight changes in environment. There is much life in the ocean. The tiny green plants of the ocean, and certain small animals that feed on them, are called **plankton.** Most plankton are **diatoms,** one-celled green plants. **Aquaculture** is the name given to "farming" the oceans. Someday these waters may provide much more of man's food.

Scientists are trying to find better ways to "mine" the minerals that are on the floor of the ocean. Such minerals are in the form of **nodules,** or lumps.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

aquaculture	continental shelves	fathoms
aqualung	convection	nodules
bathyscaphe	density	slopes

You Have a Choice

Write the numbers 1 to 5 in your notebook. Next to each number, write the letter of the choice you make.

1. The depth of the ocean is measured in
a. feet *b.* fathoms *c.* meters *d.* yards

2. The process causing the movement of water is
a. gravity *b.* radiation *c.* convection *d.* conduction

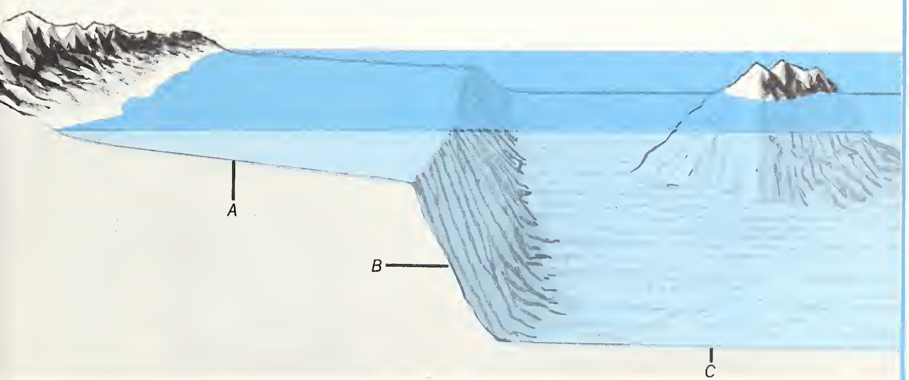
3. The basic food of the sea is
a. plankton *b.* fish *c.* nodules *d.* seaweed

4. Free diving is possible because of the
a. bathysphere *b.* bathyscaphe *c.* holdfast *d.* aqualung

5. Minerals are found on the ocean floor in the form of
a. plankton *b.* fathoms *c.* nodules *d.* diatoms

Divide the Ocean Bottom

Look at the diagram of the bottom of the ocean. On a separate piece of paper write the names of the parts labeled *A*, *B*, and *C*.



You Have a Choice:

1. b
2. c
3. a
4. d
5. c

Divide the Ocean Bottom:

A. Continental shelf

B. Continental slope

C. Floor

TEACHING SUGGESTIONS
(pp. 354–355)

Background: These pages reinforce the concepts presented in the unit by suggesting activities that extend the pupil's ability to apply the learnings derived from the unit.

What Is It?

1. Blind fish—animal
2. Diatoms—plants
3. Nodules—minerals
4. Seaweed—plant

Fill In the Life Cycle:

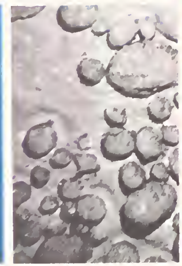
From right to left: plankton plants, plankton animals, fish and other marine animals.

YOU CAN LEARN MORE ABOUT

Probing the Oceans

What Is It?

Look at the four pictures. What does each picture show? Which are plants, which animals, and which minerals?

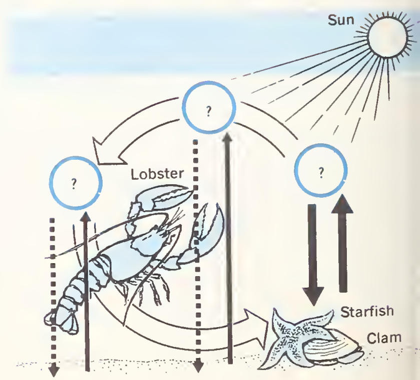


Fill in the Life Cycle

At the right is a drawing showing only some of the parts of a life and food cycle in the ocean. On a separate sheet of paper, draw the same picture. From the list below, fill in the missing parts of the cycle.

plankton plants
plankton animals
fish and other marine animals

What do the arrows show?



You Can Visit

Perhaps there is an aquarium near where you live. If so, plan a visit there with your class or with your parents. Try to find out what the various kinds of sea life are fed. From what parts of the world does the sea life come? Does each type of animal need a special temperature to survive? What kinds of animal life can live together? How were the animals captured, and what kinds of special devices were used to bring them to the aquarium?

You Can Read

1. *Ocean Harvest: The Future of Oceanography,* by Helen W. Vogel and Mary L. Caruso. Tells about the vast animal, mineral, and plant wealth in and beneath the ocean.
2. *See Along the Shore,* by Millicent E. Selsam. Tells about forms of life along the shore and their fight to survive.
3. *The First Book of the Ocean,* by Sam and Beryl Epstein. Discusses the tides, resources, plants, and animals of the sea.
4. *In the Deep Blue Sea,* by Elizabeth Morgan. A beginner's guide to the study of oceanography.
5. *All About the Sea,* by Ferdinand C. Lane. Continents, waves, currents, tides, salinity, and marine life are covered.

You Can Read:

Here is a bibliography on oceanography for teachers:

Frontiers of the Sea, by Robert C. Cowen (Doubleday, 1960).

The Open Sea, by Sir Alister Hardy (Houghton Mifflin, 1965).

Under the Sea, by Maurice Burton (Franklin Watts, 1960).

The Edge of the Sea, by Rachel Carson (Houghton Mifflin, 1955).

The Sea Around Us, by Rachel Carson (Golden, 1958).

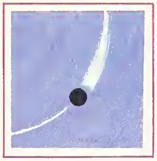
MATERIALS CHECKLIST

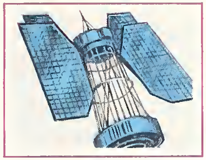
	MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
Unit 1	penny with imperfect edge 2 new pennies			
Unit 2	bits of thread, hair, soil, and salt microscope glass slides cover slides magnifying glass strips of newspaper aluminum foil cloth leaf			

Do You Remember?

Chemists study the *physical* and *chemical properties* of all substances. They observe substances and describe how they behave. Chemical properties are those that can be observed when a substance changes after combining with another substance. Physical properties are those that can be observed without causing the substance to change into something else. All substances are *matter*. Every substance known is in one of three states: *solid*, *liquid*, or *gas*. Some substances can change from one state to another. Chemists study the *melting point*, *boiling point*, and *freezing point* of substances. These are the temperatures at which substances change state. They also study *solutions* of various kinds. Chemists have learned that all matter is made of *elements*, which in turn are made of *atoms*. Atoms combine to form *molecules*. When the atoms of two or more different kinds of elements combine in a molecule, they form a *compound*. A chemical *formula* tells how many and what kinds of atoms there are in a molecule of a substance.

Other scientists, called *meteorologists*, study the weather. They study how air behaves. They are most interested in the air that makes up the earth's *atmosphere*. The earth's atmosphere has five layers—the *troposphere*, *tropopause*, *stratosphere*, *ionosphere*, and *exosphere*. Meteorologists keep records of what occurs in the earth's atmosphere. To do this they use *thermometers* to measure atmospheric temperature and *barometers* to measure atmospheric pressure. They study how the sun warms various parts of the earth. They also study *visibility*, clouds, wind, *humidity*, and *precipitation*. The meteorologist has many different kinds of instruments to help him






do his work. The meteorologist uses all the information he collects to *forecast* the weather.

The space beyond the earth's atmosphere, outer space, is also a challenge to the curiosity of scientists. Scientists have developed *rocket engines* powerful enough to lift spacecraft into outer space. Newton's Third Law of Motion—for every *action* there is an equal *reaction*—is the principle behind the way rockets work. To reach outer space, rockets must overcome the earth's gravitational pull. The force of a rocket engine is called the *thrust*. To gain thrust, rocket engines use special fuels and special designs. If a rocket has enough thrust, it can send something fired at the proper angle into *orbit*. Spacecraft that orbit the earth are designed for various purposes, such as collecting information about radiation, taking pictures of clouds, and taking temperatures in space. Spacecraft that explore far into outer space are called *space probes*. Many scientists work on the problem of sending men into space.

Scientists explore not only the far reaches of outer space, but also the depths of the oceans. The study of the oceans and seas is called *oceanography*. Scientists explore the oceans in their search for the answers to some of man's problems. Scientists turn to the sea as a source of food for the increasing population of the earth. They seek materials in the oceans to take the place of natural resources on land that are being used up. They turn to the oceans for answers to their questions about how the earth and living things came about. Man also explores the oceans for the same reasons he explores other parts of his world—because he is curious about the unknown.

MATERIALS CHECKLIST

butterfly wing
single-edge razor blade
piece of cork
iodine thinned with water (1 part iodine to 2 parts water)
flat toothpicks
medicine dropper
onion
spoon
cooking oil
covered jar of water
drop of homogenized milk
egg white
cup of soil

MATERIALS CHECKLIST

	MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
Unit 2 (cont.)	quart jar of water, and cover for jar clay			
Unit 3	dozen fertilized chicken eggs 2 cardboard cartons (one about 10″ x 10″ x 15″; the other about 12″ x 12″ x 17″ or larger) socket light bulb (adequate for keeping temperature in box at about 103° F.) lamp cord			

Dictionary of Science Words

action-reaction. The principle of Newton's Third Law of Motion, which states that for every force there is an equal and opposite force. (p. 274)

addict (AD-ikt). A person who misuses certain drugs and takes the drugs regularly. (p. 154)

adrenal gland(s) (ad-REE-n'l). Two glands, one on each kidney, that release chemical hormones directly into your blood. These hormones cause automatic changes in your body, which help you to have quick energy when needed. (p. 116)

algae (AL-jee). Plants containing chlorophyll that grow in water. (p. 295)

allergic (uh-LER-jik). Sensitive to a specific substance. (p. 153)

anthrax (AN-thrakss). A cattle and sheep disease studied by the German scientist Robert Koch. (p. 131)

antibiotic (an-tih-by-OT-ik). A substance produced by living organisms, such as bacteria, molds, or fungi, that fights germs. (p. 151)

antibodies (AN-tih-bod-eez). Chemical substances that develop in your blood when an organism enters your body. Antibodies help you fight off infections. (p. 147)

antiseptic (an-tih-SEP-tik). As free of germs as possible. (p. 142)

aquaculture (AK-wuh-kul-cher). Farming the seas. (p. 343)

aqualung. A piece of equipment that enables people to breathe while underwater. (p. 315)

arteriosclerosis (ahr-teer-ee-oh-skler-OH-siss). The disease in which there is a thickening of the lining of the arteries. (p. 155)

artery (AHR-ter-ee). A blood vessel that carries blood away from the heart to the capillaries. (p. 84)

artificial gravity. A force, similar to the force of gravity, produced by the circular motion of a machine called a centrifuge. (p. 290)

assumption (uh-SUMP-shun). Something that is believed to be true. An assumption may or may not be correct. (p. 133)

astronaut (ASTRUH-nawt). An American space pilot. (p. 288)

atmosphere (AT-muss-feer). The total amount of air all around the earth. (p. 216)

atmospheric pressure. The pressure of the air on the earth. It is about 14.7 pounds per square inch at sea level. (p. 223)

atom. The smallest piece of any kind of matter that cannot be further divided by ordinary means. Atoms are the building blocks of all matter in the universe. (p. 191)

atomic mass. The total number of particles in the nucleus of an atom. (p. 200)

barometer (buh-ROM-uh-ter). An instrument to measure atmospheric pressure. (p. 227)

bathyscaphe (BATH-ih-skayf). A deep-sea diving balloon that has enabled scientists to plunge to a depth of almost seven miles. It was invented by Auguste Piccard. (p. 316)

bladder (BLAD-er). The part of the body into which urine flows from the kidneys. (p. 94)

boiling point. The temperature at which a liquid starts to boil. Water boils at 212° F., or 100° C. (p. 173)

cancer. A disease in which cells grow out of control, destroying normal cells that are near them. (p. 154)

capillary (KAP'l-ehr-ee). The thinnest blood vessel in the body. It is only one cell thick. Capillaries connect arteries and veins. (p. 84)

cell(s). The tiny bits of living matter of which all plants and animals are made. (p. 24)

cell membrane (MEM-brayn). The thin living material that covers a cell. (p. 33)

cell theory. The theory published in 1838 and 1839 by two German scientists named Theodor Schwann and Matthias Schleiden, which says all living things are made of one or more cells or of cells and their products. (p. 7)

cellulose (SEL-yoo-lohss). The cell walls of plants are made of cellulose. Cellulose cannot be digested. (p. 33)

cell wall. The structure, made of cellulose, that surrounds the cell membrane of a plant cell. (p. 33)

centrifuge (SEN-truh-fyooj). A machine whose circular motion produces a force similar to the force of the earth's gravity. (p. 290)

cerebellum (sehr-uh-BEL-um). The part of the vertebrate brain that automatically takes care of co-ordination, or smooth action of the muscles. (p. 107)

cerebrum (SEHR-uh-brum). The part of the vertebrate brain involving thinking. (p. 108)

chemical property. A property that determines how a substance combines with another substance. (p. 169)

chemical reaction. A chemical change that results when substances combine. (p. 179)

chrysalid (KRISS'l-id). The case a butterfly spins around itself in the pupa stage. (p. 66)

circulate (SER-kyoo-layt). To move throughout and return to the same point. Your blood circulates through your body. (p. 80)

cirrus cloud(s) (SIR-uss). Thin, fast-moving clouds, whose bottoms are sometimes 10 miles from the ground. Often they are formed ahead of a cold or a warm air mass. They are a sign of bad weather. (p. 231)

cold front. A place where a cold air mass moves forward. (p. 240)

colony. A grouping together, in a culture, of one kind of bacteria. (p. 132)

compound (KOM-pownd). A combination of two or more different kinds of atoms in one or more molecules. (p. 192)

computer (kum-PYOO-ter). An electronic machine that can be "fed" information and that can give back information. (p. 253)

continental shelves. The parts of the ocean bottom nearest to the continents. The shelves are the shallowest parts of the ocean. (p. 318)

convection (kun-VEK-shun). The process that causes currents in a gas or liquid. (p. 332)

cosmic rays (KOZ-mik). High-speed atomic particles from outer space. (p. 268)

cosmonaut (KOZ-muh-nawt). A Russian space pilot. (p. 288)

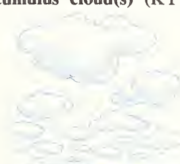
crop. The part of a chicken's body where undigested food is stored. (p. 91)

crystal. A solid substance having a regular, fixed shape. (p. 181)

cubic. Six-sided, like some crystals. (p. 182)

culturing (KUL-cher-ing). A way of growing bacteria in the laboratory. (p. 132)

cumulus cloud(s) (KYOOM-yuh-luss). Light, puffy clouds, which form when warm air containing water vapor rises and the water vapor begins to condense. They are often not more than a mile high. (p. 229)



cytoplasm (SY-tuh-plaz'm). The material around the cell nucleus. (p. 33)

deficiency disease (dih-FISH-un-see). A disease caused by lack of nutrients. (p. 124)

degenerative disease. Occurs when a body organ begins to wear out. (p. 24)

MATERIALS CHECKLIST

- asbestos paper (10″ x 10″)
- aluminum foil
- wall thermometer
- thermostatic switch
- aluminum cake pan (about 7″ x 9″)
- wire mesh (about 11″ x 13″)
- razor blade
- clothespin
- pane of glass
- tape
- stapler
- water
- crumpled newspaper
- corks (about 1″ in diameter)

Unit

MATERIALS CHECKLIST

MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
Unit 3			
notebook paper			
scissors			
2 dishes or bowls			
28 paper towels			
32 lima-bean seeds			
10 radish seeds			
10 pea pods			
10 corn seeds			
2 germination dishes			
pot or can of soil			
frogs' or toads' eggs			
large pails			

density (DEN-suh-tee). The relation between the mass of an object and the amount of space that it takes up. (p. 331)

diaphragm (DY-uh-fram). A muscular wall that separates the chest from the lower part of the body. It moves up and down, causing the lungs to be full or empty of air. (p. 92)

diffusion (dih-FYOO-zhun). The movement of molecules from a place where there are many to where there are fewer. (p. 8)

digestive system (dih-JESS-tiv). The body system that includes your mouth, gullet, stomach, small intestine, and large intestine. (p. 88)

disinfectant (diss-in-FEK-tunt). A chemical, such as soap, that kills germs. (p. 139)

ectoderm (EK-tuh-derm). The outer layer around the ball of cells of a developing egg cell. (p. 49)

electron (ih-LEK-tron). A negatively charged particle that moves in an orbit around the nucleus of an atom. (p. 199)

element(s) (EL-uh-ments). The substances from which all matter in the universe is made. (p. 189)

embryo (EM-bree-oh). The earliest stages of an animal, after an egg cell has been fertilized. (p. 47)

embryology (em-bree-OL-uh-jee). The science of the early development of living things. (p. 49)

endoderm (EN-duh-derm). The inner layer of the ball of cells in a developing egg. (p. 49)

escape speed. A horizontal speed of about 7 miles a second, which enables a spacecraft to escape the earth's gravity. (p. 286)

evaporated. Changed from a liquid to a gas. Water has evaporated when it has changed from liquid water to water vapor. (p. 216)

excretory system (EKS-krih-tor-ee). The system in your body that enables you to get rid of wastes. (p. 93)

exosphere (EK-suh-sfeer). The highest layer of the earth's atmosphere. (p. 219)

fathom (FATH-um). A depth measurement of 6 feet in water. (p. 320)

fertilize (FER-t'l-yz). To join the nucleus of a sperm cell with the nucleus of an egg cell. (p. 47)

filter(s). The parts of the kidney that strain urine out of the blood. (p. 94)

firing chamber. The part of a rocket engine in which burning fuels produce hot gases. The hot gases rush out through the exhaust nozzle of the rocket engine. (p. 274)

floor(s). The deepest parts of the ocean. Man knows very little about them. They are a world of complete darkness. (p. 320)

formula (FOR-myoo-luh). In chemistry, a short way to write things, which tells the number of atoms of each element in a molecule of a substance. (p. 194)

freezing point. The temperature at which a liquid becomes solid. The freezing point of water is 32° F., or 0° C. (p. 173)

gas. The state of matter in which a substance completely fills its container. Air is a gas. (p. 172)

germination (jer-muh-NAY-shun). The development of a plant's leaves, stem, and roots. (p. 59)

germ theory of disease. The theory that infectious diseases are transmitted by specific microorganisms. (p. 131)

G force. A force equal to the normal force of the earth's gravity. During take-off, astronauts experience forces of several G's. (p. 291)

gizzard. The part of a chicken's body in which food is ground against small stones to prepare it for digestion. (p. 91)

gland(s). Parts of the body that release hormones directly into the blood, causing chemical changes in the body. The adrenals are glands. (p. 115)

heart disease. A disease that affects the heart, such as improper development of the heart before birth or rheumatic fever. (p. 154)

high-G force(s). Strong forces, much greater than the normal force of gravity. (p. 292)

hormone (HOR-mohn). A chemical causing automatic changes in the body after it is released by a gland into the blood. (p. 70)

hurricane (HUR-ih-kayn). A very strong storm. (p. 251)

hygrometer (hy-GROM-uh-ter). An instrument used by meteorologists to measure relative humidity. (p. 233)

hypothesis (hy-POTH-uh-siss). A possible answer to a problem. (p. 3)

immune (ih-MYOON). Having the ability to resist a disease. (p. 146)

incubation period. The temperature-controlled period of development required before an animal comes out of its egg. (p. 48)

incubator (ING-kyoo-bay-ter). The temperature-controlled container in which fertilized eggs are kept. (p. 48)

infectious disease (in-FEK-shuss). A disease that is passed on from one living thing to another. It is caused by germs that infect the body. (p. 124)

International Geophysical (jee-oh-FIZ-ih-k'l) **Year.** The name given to the year 1957-58, during which scientists all over the world cooperated in studying the earth. (p. 251)

ion (EYE-un). An atom that is no longer neutral, because it has lost or gained electrons. (p. 203)

ionosphere (eye-ON-uh-sfeer). The layer of the earth's atmosphere above the stratosphere. (p. 218)

irradiation (ih-ray-dee-AY-shun). A way of passing ultraviolet and X rays through foods to preserve the foods. (p. 297)

isobar (EYE-suh-bar). A line on a weather map, joining places where atmospheric pressure is the same. (p. 238)

jet stream(s). Winds which travel eastward at great speeds in the tropopause. (p. 218)

jointed. Having a joint, a place where the end of one bone meets the end of one or more other bones. Your elbow is a joint. (p. 96)

kidney(s) (KID-neez). The two organs into which wastes flow after they have been carried from the cells by the blood. (p. 94)

large intestine. The part of the body through which undigested food passes after it leaves the small intestine. (p. 88)

larva (LAHR-vuh). The wormlike stage in the development of certain animals. (p. 62)

liquid. The state of matter in which a substance takes the shape of its container and remains at the bottom. (p. 172)

malaria (muh-LAIR-ee-uh). A disease caused by protozoa (one-celled animals). (p. 138)

melting point. The temperature at which a substance changes from solid to liquid. (p. 173)

mesoderm (MESS-uh-derm). The middle layer of the ball of cells of a developing egg. (p. 49)

meteorologist (mee-tee-uh-ROL-uh-jist). A scientist who studies the weather. (p. 225)

microorganism (my-kroh-OR-gun-iz'm). An organism too small to be seen by the unaided eye. (p. 127)

millibar(s) (MIL-uh-bahrz). The units in which atmospheric pressure is measured. (p. 238)

molecule (MOL-uh-kyool). A combination of two or more atoms. (pp. 34, 191)

Motion, First Law of. The scientific law stating that an object at rest remains at rest, and one in motion continues in motion in a straight line and at the same speed, unless an outside force acts on it. (p. 280)

Motion, Second Law of. The scientific law stating that the rate at which the speed of an object changes depends on two things: the mass of the object and the force applied to it. (p. 280)

MATERIALS CHECKLIST

Unit 3 (cont.)	pond water gallon glass jars or other containers magnifying glass medium-sized jar screen or netting to cover jar cuttings auxin photographs of a student's parents, at various ages photographs of that student, at various ages
Unit 4	glass of water ink (preferably India ink)

MATERIALS CHECKLIST

	MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
Unit 4 cont.	magnifying glass			
	8″ x 10″ paper			
	rubber bands			
	teaspoon			
	cornstarch			
	sugar			
	2 glasses of water			
	iodine			
	medicine dropper			
	paper towel			
	lamp chimney			
	two-holed rubber stopper			

Motion, Third Law of. The scientific law stating that for every action (force) there is an equal reaction (opposite force). (p. 272)

motor nerve. A nerve that carries messages away from the brain or spinal cord. (p. 106)

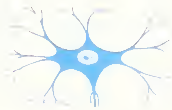
multistage rocket. A spacecraft that is made up of two or more rockets. (p. 282)

muscle(s). Parts of your body that help you to move. (p. 96)

mutant (MYOO-tunt). Among bacteria, an offspring of a bacterium that is not exactly like the original bacterium. The offspring of the mutant will be like the mutant, not like the original bacterium. (p. 152)

nerve(s). The thin, threadlike parts of the body that carry messages to and from the brain and spinal cord. (p. 101)

nerve cell(s). Cells that make up the nerves of your body. The quite thin parts of the cell that extend from the cell body are *dendrites.* (p. 101)



nervous system. The system of the body that includes the brain, spinal cord, and nerves. Your nervous system helps you adjust to changes and helps you change the world about you. (p. 101)

neutron (NOO-tron). An electrically neutral particle in the nucleus of an atom. (p. 199)

nodule (NOD-yool). A lump of minerals found on the ocean floor. (p. 348)

nucleus (NOO-klee-uss). The part of a cell that directs the growth and reproduction of the cell. *Nucleus* is also the name for the part of an atom that contains protons and neutrons. (pp. 33, 196)

oceanography (oh-shun-OG-ruh-fee). The study of the oceans and seas. (p. 312)

orbit (OR-bit). The path of one object around another. Electrons make orbits around the nuclei of atoms. (p. 199)

organ. A group of tissues that work together. (p. 38)

organism (OR-gun-iz'm). Any plant or animal. (p. 39)

organized living system. An organism. (p. 39)

ovary (OH-ver-ee). The part of an animal's body in which an egg cell is produced. *Ovary* is also the name of the thickened part of the pistil of a flower, in which ovules are produced. (pp. 47, 55)

oviduct (OH-vih-dukt). The tube through which an egg cell passes after it leaves an ovary. (p. 47)

ovule (OH-vyool). A small, round structure attached to the wall of the ovary of a flower. It contains the egg cells and becomes the seed, if the egg cell is fertilized. (p. 55)

pasteurization (pass-ter-uh-ZAY-shun). A process of killing bacteria in food so that the food will not spoil. (p. 130)

penicillin (pen-uh-SIL-in). A drug that is used against certain bacteria. (p. 151)

perspiration (per-spuh-RAY-shun). A waste product excreted through the skin—sweat. Sweat is mostly water with some salts dissolved in it. (p. 95)

physical property. A substance's property that can be observed without causing the substance to change into something else. (p. 169)

pistil. The tubelike part in the center of a flower. The ovary is the thickened part at the bottom of the pistil. In the ovary are the ovules, which can be fertilized by pollen that falls on the pistil from the stamen. (p. 55)

pituitary gland (pih-TOO-uh-tehr-ee). A gland located in the head, just beneath the brain. A hormone produced by the pituitary gland regulates the rate of bone growth. (p. 70)

plankton (PLANK-tun). Tiny green plants of the ocean and certain small animals that feed on them. (p. 339)

pneumonia (noo-MOH-nyuh). A respiratory disease caused by bacteria. (p. 133)

pollen. The powdery material, on top of each stamen, whose nuclei fertilize the ovule cells of the flower. (p. 55)

precipitation (prih-sip-uh-TAY-shun). The falling of some form of water, such as rain or snow. (p. 233)

probability theory. The way that scientists figure out the number of possible events and how likely each of them is to occur. (p. 12)

proton (PROH-ton). A positively charged particle in the nucleus of an atom. (p. 199)

protozoa (proh-tuh-ZOH-uh). Tiny one-celled animals. (p. 127)

pupa (PYOO-puh). The stage in the development of an insect in which the insect lives in a case that it made in the larval stage. (p. 63)

radar (RAY-dahr). An instrument that sends out radio waves and receives them after they are reflected back by an object. Radar indicates the direction and distance of the reflecting object. (p. 236)

radiation (ray-dee-AY-shun). A treatment for cancer. Scientists beam radiation at cancer cells to kill or slow down the cells. (p. 156)

reaction (ree-AK-shun). A force that is the result of an opposite force. (p. 274)

reflect. To bounce back. Radar waves are reflected when they hit an object. (p. 236)

reflex (REE-flekss). The activity that follows from a nerve message that goes from nerve endings to your spinal cord and then to a muscle. A reflex is automatic. (p. 113)

relative humidity (yoo-MID-uh-tee). The amount of water vapor in the air compared to the greatest amount that *could* be in the air at a specific temperature. (p. 232)

resistant. Able to resist the killing effect of an antibiotic. (p. 153)

respiratory system (rih-SPYR-uh-tor-ee). The system of the body that consists of the windpipe, lungs, and diaphragm. (p. 92)

rocket (ROK-it). A spacecraft that can lift men and instruments into outer space. (p. 271)

roughage (RUF-ij). Undigestable parts of fruits and vegetables. (p. 90)

salinity (suh-LIN-uh-tee). The saltiness of a mixture or solution. (p. 332)

saliva (suh-LY-vuh). The liquid in your mouth that helps in digesting food. (p. 88)

salivary gland(s) (SAL-uh-vehr-ee). The glands in the mouth from which saliva flows. (p. 90)

satellite (SAT-uh-lyt). An orbiting object, such as one that has been carried into outer space by a rocket. (p. 271)

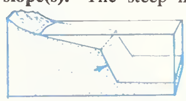
saturated. Containing as much of a dissolved substance as is possible. (p. 176)

scale drawing. A drawing that uses a fixed, other unit of measurement to equal each larger unit of measurement. (p. 69)

scurvy (SKER-vee). A deficiency disease caused by a lack of vitamin C. (p. 154)

sensory nerve(s) (SEN-ser-ee). Nerves that carry messages of taste, hearing, sight, smell, and touch to your brain. (p. 106)

slope(s). The steep hills that drop from the



continental shelves to the ocean floor, ending in canyons and valleys. (p. 320)

smallpox. A disease against which Edward Jenner developed a vaccination. (p. 146)

solar flare. An eruption from the sun that can send dangerous rays or thick streams of atomic particles into space. (p. 300)

solid. The state of matter in which a substance has a definite shape. (p. 172)

solubility. The property of being able to dissolve in another substance. (p. 174)

soluble (SOL-yoo-b'l). Able to dissolve in another substance. (p. 174)

solution (suh-LOO-shun). A liquid in which a substance is dissolved. (p. 176)

space probe. A spacecraft that explores far into space. (p. 286)

MATERIALS CHECKLIST

Unit 4 *(cont.)*

glass Y-shaped tube
2 balloons
plant
salt
lemon
Epsom salts
mirror
small clean brush
5 cups of water
clean handkerchief
orange
razor blade
sharp toothpick
small pea

MATERIALS CHECKLIST ✓

MATERIALS CHECKLIST		QUANTITY	DATE NEEDED	SOURCE
Unit 4 (cont.)	pencil evaporating alcohol 2 pieces of wood (each 12" long x 2" wide x 1/4" thick) 3 cup hooks 4 screw eyes bolt nut strong cord drill			

sperm cell. The cell, produced in a male's body that can fertilize the egg cell. (p. 47)

spinal cord (SPY-n'l). The part of your nervous system that is attached to your brain and that stretches down your back. (p. 106)

spore(s) (sporz). Bacteria that have grown coverings around themselves. (p. 131)

stamen (STAY-mun). The pollen-producing organ in a flower. The pollen grains from the stamen fall on the pistil. They can fertilize the ovules in the ovary, which is the thickened part at the bottom of the pistil. (p. 55)

states of matter. Gas, liquid, and solid. All matter in the universe is in one of these states. (p. 170)

stationary front. A place where a warm and a cold front meet and do not move. (p. 240)

sterilized (STHR-uh-lyzd). Made free from living organisms. (p. 139)

stomach (STUM-ik). The part of the body to which food goes after leaving the gullet. (p. 88)

strain. Mutant bacteria that are resistant to a particular antibiotic. (p. 153)

stratosphere (STRAT-uh-sfeer). The layer of the atmosphere, above the tropopause, in which there is almost no weather. (p. 218)

stratus cloud(s) (STRAY-tuss). Gray sheets of clouds that cover the sky and usually indicate that rain will soon fall. *Stratus* means layer. The rain that comes from stratus clouds is usually a steady rain. (p. 231)

sulfa. A type of drug that kills certain bacteria. (p. 151)

supersaturated. Containing more of a soluble substance than can be held in a saturated solution. (p. 184)

system. A group of organs that work together. (p. 39)

theory (THEE-uh-ree). A hypothesis that tries to show connections among facts. (p. 7)

thermograph (THER-muh-graf). A heat measuring and recording instrument. (p. 226)

thrust. The force of a rocket engine. (p. 276)

tissue (TISH-oo). A group of similar cells. (p. 36)

tornado (tor-NAY-doh). A whirling mass of air with a funnel-shaped cloud. (p. 231)

trilobite (TRY-luh-byt). One of the extinct sea creatures. (p. 337)

tropopause (TROHP-uh-pawz). The layer of the atmosphere above the troposphere. (p. 218)

troposphere (TROHP-uh-sfeer). The layer of the atmosphere nearest the earth. (p. 216)

tuberculosis (too-ber-kyoo-LOH-siss). An infectious lung disease caused by bacteria. (p. 133)

urine (YOOR-in). The liquid waste that the kidneys filter from the blood. (p. 95)

vaccination (vak-suh-NAY-shun). A process of making someone immune to a disease. (p. 147)

vein(s) (vaynz). The blood vessels that carry blood back to the heart. (p. 84)

villi (VIL-eye). The "fingers" along the lining of the small intestine. Digested food passes through the capillaries in the villi into the bloodstream. (p. 91)

virus (VY-russ). A very tiny bit of protein. Some diseases are caused by viruses. (p. 134)

warm front. The place where a warm air mass is moving forward. (p. 240)

wind. Moving air. (p. 215)

windpipe. The part of the respiratory system that carries air to the lungs. (p. 92)

yolk (yohk). The yellow part of an egg, which serves as food for the embryo. (p. 47)

Dictionary of Scientists

Beadle, George W. A geneticist who studied the red bread mold (*Neurospora crassa*) to learn about the pattern of growth and development in organisms. (p. 64)

Beaumont, William. An Army physician who studied digestive processes by observing Alexis St. Martin's stomach through an opening in St. Martin's body. (p. 87)

Curie, Marie. A scientist who, with her husband Pierre Curie, won the Nobel Prize in 1903 for the discovery of radium. Madame Curie won another Nobel Prize in 1911 for the extraction of radium. (p. 14)

Ehrlich, Paul (EHR-lik). A scientist who discovered that trypan red kills the organisms that cause sleeping sickness. Ehrlich also did research with Salvarsan. (p. 150)

Einstein, Albert (YN-styn). One of the greatest scientists who ever lived. His work contributed vastly to mankind's use of atomic energy. (pp. 7, 8)

Faraday, Michael (FAR-uh-day). An English scientist whose work with magnets contributed to the development of the electric generator. (p. 13)

Fleming, Alexander. A British scientist who discovered that penicillin can kill certain germs. (p. 151)

Galen (GAY-lun). A physician, in ancient Rome, who believed that sickness is the result of an imbalance of fire, air, water, and earth in the body. (p. 126)

Goddard, Robert H. A scientist who pioneered in American rocket research. (p. 284)

Hippocrates (hih-POK-ruh-teez). A physician, in ancient Greece, who formulated the view that disease is the result of an imbalance of humors in the body. (p. 125)

Hooke, Robert. A member of the Royal Society of London who studied cork cells with a microscope and was the first to use the term *cell*. (pp. 25, 30, 33)

Jenner, Edward. An English physician who learned how to vaccinate people so they would be immune to smallpox. (p. 146)

Koch, Robert (KOHK). A German physician who studied the disease called *anthrax*. Koch developed a series of steps for scientists to follow in finding the specific germ that causes a disease. (pp. 131, 134)

Kornberg, Arthur. A scientist who won the Nobel Prize in 1959 for making deoxyribonucleic acid (DNA). (p. 28)

Laënnec, Théophile (lay-NEK). A physician who invented the stethoscope. (p. 86)

Lavoisier, Antoine Laurent (an-TWAHN lah-vwah-zee-AY). A French chemist who said that, in burning, the material that burns combines chemically with oxygen. Lavoisier also pioneered in chemical terminology. (p. 170)

Leeuwenhoek, Anton van (LAY-vun-hook). The Dutch scientist who made one of the first microscopes and used it to study microorganisms. (pp. 6, 127)

Lister, Joseph. An English surgeon who found that carbolic acid sprayed in the air will sterilize the air. Lister's discovery has helped reduce the risk of infection in surgery. (pp. 138, 142, 150)

MATERIALS CHECKLIST

Unit 5

- pond water
- microscope
- 4 glass slides
- 4 cover slides
- cup of water
- clean white cloth
- hot plate
- pan
- dead grass, hay, or straw
- eye dropper
- rubber bands
- several boiled potatoes
- clean knife
- water

MATERIALS CHECKLIST

Unit	MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
5 (cont.)	several clean plates ammonia lysol bleach soap 2 quarts of pond water containing protozoa 4 paper cups dried beans alcohol 4 test tubes iodine			

Maury, Matthew Fontaine. An American pioneer in oceanography who is called the "father of oceanography." (p. 318)

Newton, Isaac (NOO-t'n). An English scientist who formulated the Laws of Motion. (pp. 272, 292)

Ochoa, Severo (oh-CHOH-uh). A university professor who won the Nobel Prize in 1959 for making ribonucleic acid (RNA) in the laboratory. (p. 28)

Pasteur, Louis (pass-TER). A French chemist who discovered that heat can kill bacteria, which enter foods from the air. He also formed the germ theory of disease. (pp. 129, 142)

Pavlov, Ivan Petrovich. A Russian scientist who studied the role of the nervous system in digestion. Pavlov also studied the learning process. (p. 110)

Piccard, Auguste (pee-KAHR). A Swiss scientist who invented a closed gondola to explore space. Piccard also investigated cosmic rays and invented the bathyscaphe. (pp. 268, 316)

Salk, Jonas E. An American physician who helped to find a vaccine that makes most people immune to polio. (p. 148)

Schleiden, Matthias (SHLY-den). A scientist who, with Theodor Schwann, formed the theory that all living things are made up of cells. (pp. 6, 27)

Schwann, Theodor (SHVON). One of the scientists who formed the theory that all living things are made up of cells. (pp. 6, 27)

White, Robert M. A meteorologist who, in 1963, became Chief of the United States Weather Bureau. He developed new ways to broadcast weather forecasts. (p. 254)

Checklist of Science Activities

Here is a list of some things you can learn to do as you read this book. At the end of each unit there are four pages that tell you other things you can do.

1 The Scientist's Way

Testing to see if air pushes on things	2
Testing some hypotheses	5-6
Learning who is an expert	9
Testing the probability theory	11-12
Testing a coil magnet	13
Changing one of Faraday's experiments	16
Testing hypotheses by experimenting	16
Knowing where to find answers	17

2 Cells, Tissues, Organisms

Comparing different microscope photographs	28
Understanding microscope lenses	30
Making size comparisons using a microscope	30
Looking at things with a microscope	30
Examining a cork layer with your microscope	30

MATERIALS CHECKLIST

Unit 5 (cont.)	sterile absorbent cotton old pan 2 perfect apples 1 partly rotten apple 2 needles penicillin tablet antiobiotics other than penicillin	
Unit 6	balance scale ruler block of wood sulfur teaspoon 2 large test tubes	

MATERIALS CHECKLIST

Unit 6 (cont.) MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
hot plate			
table salt			
cup			
teaspoonful of sugar			
teaspoonful of calcium carbonate			
water			
test-tube holder			
moth ball			
pan			
stand to hold pan			
hypo			
cold bottle of soda			

MATERIALS CHECKLIST

Unit 6 (cont.)

2 heat-resistant glasses
barium sulfate
silver nitrate
granite
quartz
Epsom salt
heat-resistant glass jar
box of toothpicks
soft wax or gumdrops
seed crystal
cellophane to cover jar
10 ounces of alum
saucer
Mason jar

MATERIALS CHECKLIST

MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
Unit 6			
tweezers			
salol powder			
magnifying glass			
several copper sulfate crystals			
several sodium chloride crystals			
balsa sticks			
slide projector			
screen for viewing slides			
construction paper			
large piece of rock salt			
hammer			
ammonium dichromate			

Index

MATERIALS CHECKLIST

chromium potassium sulfate
cobalt chloride
iron filings
magnet
large pyrex test tube
baking soda
vinegar
tarnished silver object
rubber stopper
small ball of metal foil
drill
copper filings
copper sulfate solution, $CuSO_4$
ferric chloride solution, $FeCl_3$

Unit 6 (cont.)

MATERIALS CHECKLIST

Unit	MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
7	yardstick sand inflated soccer ball pin from soccer ball clear plastic or heavy celluloid box (about 1 foot long, 1 foot wide, and 10 inches high) ping-pong balls and golf balls (enough to fill box) 2 jars of the same size, with lids 2 pieces of the same cloth, 1 by 2 inches 2 thermometers			

MATERIALS CHECKLIST

Unit 7 (cont.)

- glass tube 36" long, one end closed
- mercury in small pan or dish
- narrow jar with straight sides and a flat bottom
- wide jar with straight sides and a flat bottom
- weather map
- barometer
- cloud charts
- wind vane
- visibility chart
- air-speed chart, or anemometer
- wet-bulb and dry-bulb thermometers or a hair hygrometer

MATERIALS CHECKLIST

Unit	MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
8	long balloons			
	wire			
	balsa stick (1/4-inch square and 12 inches long)			
	25 feet of nylon sewing thread			
	kitchen scale			
	brick			
	spring scale			
	4 small wheels			
	2 pieces of balsa wood (1/4 by 2 by 3 inches; and 1/4 by 2 by 4 inches)			
	4 nails			

MATERIALS CHECKLIST

- garden hose attached to water source
- plywood (3/4 inches by 1 foot square)
- 2 corner blocks (2 by 4 by 4 inches long)
- rubber strip (1 by 15 inches) cut from an old tire tube
- piece of angle iron or aluminum track
- elodea (from a pond, aquarium, or pet shop)
- small test tube
- 1 tablespoon of salt
- transparent food-wrapping paper or plastic bag
- 3 metal cans of the same size
- 3 room thermometers

MATERIALS CHECKLIST

Unit	MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
Unit 8 (cont.)	black and white tempera paint soil several sterilized Petri dishes agar several 8-inch pieces of damp sterilized string			
Unit 9	pint of sea water 3 tablespoons of salt sea shells a fish from a market scalpel			

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TEACHERS' GUIDE FOR *BOOK 5*

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Science for Tomorrow's World

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Teachers' Guide for *Science for Tomorrow's World*

In most elementary schools, it is the classroom teacher rather than a specialist in science education who teaches science. Thus, the classroom teacher must have some knowledge of the subject matter of science as well as an awareness of how children learn. The Teachers' Guide of *Science for Tomorrow's World* provides help in both of these areas. We include supportive factual information to strengthen what the teacher already knows about science, as well as teaching suggestions based on the present knowledge of how children learn.

To be truly effective as a teacher of science, the teacher must have an understanding of what science *is* and what a scientist *does*. We often hear that the American child of today is growing up in a scientific age. What does this really mean? What exactly *is* sci-

ence? The answer to this last question will determine the teacher's approach and orientation to every lesson presented. To help the teacher gain a fuller understanding of the climate of our scientific age, we begin the Teachers' Guide with a discussion of the meaning of science and the work of the scientist.

SCIENCE AND THE SCIENTIST

Science is the study of natural phenomena; it concerns itself with describing such phenomena and attempting to explain them through laws that constantly can be tested and corrected against consequences in experience. These scientific laws are then fitted into a working model of the universe—a model that may be in the form of an idea, a diagram, or a construction (Book 6, p. 145). Often, scientists must do many experiments before a working model can be developed. Often, too, many experiments and much theorizing are done after the model is developed, in order to determine whether or not the model is accurate. An accurate working model may be highly useful in predicting future events. With a working model of the solar system, for example, it is possible to make predictions about when eclipses will occur, when Mars will be closest to the earth, when tides will be high, and where the earth will be in relation to other planets at any given time in the future. In some instances, a working model also helps to control man-made or natural phenomena. A model of motion that approximates natural motion is indispensable in controlling man-made motions such as those of a primitive oxcart or a modern space satellite. This is not to imply that science is concerned with prediction and control for practical reasons only. Such concern has grown out of man's need to dispel uncertainty, to know the world in which he lives.

In constructing a foundation for a model of reality, the scientist uses ideas of time, space, matter, causality, and number. In each of these areas, the scientist believes there is order; things do not happen in a haphazard fashion in the world of nature, but in a logical, noncontradictory manner. Thus, no matter what year, no matter what season, the sun always appears at dawn in the east. No matter what kind of projectile is launched from the earth into space, the projectile has two kinds of motion—a forward motion in the direction in which it was launched and a downward motion in the direction of the center of the earth.

From the dawn of history, man has sought to explain what he observed and then to use his explanations to predict future events. Even long ago, scientists believe, man was able to predict certain natural phenomena. They believe that an ancient people at Stonehenge, England, studied the movements of earth and sun and were able to place great rocks in such a fashion as to predict the beginning and ending of seasons and eclipses. We can find countless other examples to show that the order in the universe became evident to man's intelligence and that he used the test of prediction to prove the existence of that order. For example, at Stonehenge, it is believed that if ancient man's notions about movements of sun and earth were wrong, the sun would not have been seen rising over a particular stone on a particular day of the year; thus, the concept would have to have been changed accordingly. Sometimes when ancient man was unable to find an explanation for natural phenomena, he resorted to magic. Through magic, he thought himself able to explain a particular event, not by recourse to natural laws, but by the invention of uncontrollable "somethings" that he believed might yield to magical rites.

Why did man gradually give up magic and turn more and more to a search for natural laws? Psychologists find the explanation in the part of man's biological inheritance that is intelligence—a form of mental adaptation that causes man to seek to deal effectively with his environment. This basic need produces a tendency to give up explanations that do not conform to reality. Reality comes to be not what one perceives with the senses, but rather the product of trans-

formations that one performs upon data in the mind. A distant elm may appear to be smaller than a nearby birch sapling, but the mind puts each tree in proper spatial perspective. It may have seemed to ancient man that the sun traveled around the earth, but such a concept of the solar system is not consistent with all the known facts, and so man eventually constructed a more realistic concept of the solar system.

It is evident that science involves more than just the accumulation of new facts about the universe. Galileo's "facts" about motion are already known to anyone who has rolled an object down an inclined plane or thrown an object from a moving vehicle. All the facts needed to derive the concept of gravitation were known to man long before Newton. The great forward leaps in science have often come about not because man discovered new facts about the universe, but because a great scientific mind saw those same facts in a new framework. The search for new facts goes on continuously in scientific laboratories, but the major breakthroughs take place inside the minds of scientists themselves.

How do these breakthroughs occur? What does man look for to make the world more intelligible? Two guiding principles stand out: Man looks for *unity*, and he looks for *simplicity*.

To look for unity means to look for likenesses, often in unexpected places. It means, for example, seeing that the model of the solar system might also serve as a model for the atom. It means seeing similarities among the ant, the fish, the mouse, and man. For convenience, man may divide science into the study of the physical and the biological—the living and nonliving. But man searches for more than merely a similarity between any two related facts; he searches for a law that will explain *all* such related facts, and thus he strives toward unity.

The second guiding principle in man's striving to make the world more intelligible is that of simplicity. Man seeks the basic units—ultimate and fundamental units—out of which more complex matter is built. The discovery of the cell and the discovery of the atom were two milestones in man's striving toward simplicity. Present-day explorations of molecular activity in the cell lead further in the direction of unity and simplicity; eventually, the activities of all living things may be explained in terms of atoms.

In preparing *Science for Tomorrow's World,* the authors have been guided by a modern viewpoint of science. We have constantly asked ourselves what this modern viewpoint implies for science education in elementary schools. We turn now to a consideration of those implications which have guided our thinking in the planning and developing of this series.

A PHILOSOPHY OF SCIENCE EDUCATION

Three basic principles form the foundation of our approach to science education. First, we affirm our faith in the *natural curiosity of the child* as a *powerful motivating tool in acquiring science knowledge. We* believe that this curiosity can be kept at a high level, not necessarily by the use of bizarre or dramatic science activities, but by making explicit to the child the difference between his own view of reality and reality as it actually exists—as well as man can conceive of it. The child brings with him to the classroom a tremendous body of cognitive structures that he uses to explain the universe. The problem in teaching science to children is not that the child does not have explanations for natural phenomena; it is rather that his explanations are often either half-correct or wholly incorrect. Yet, if we can assume on the part of the child a basic urge to deal effectively with his environment, when he becomes aware of the discrepancy between what he believes and what is reality, we can then conclude that he will be more ready to apply the use of logic in his thinking. Here, both deductive and inductive (discovery) processes are invaluable. Some key concepts can best be taught by direct presentation that

is followed by applications of the key concepts to a wide variety of data. Thinking can be stimulated when the teacher says, for example, "How does what we have learned about sound apply to a mammal such as the bat? How can the bat's sense of hearing help the bat to know when an object is near?"

The discovery method is most effective when reserved for the induction of certain general laws. For example, in the study of animal behavior, children can discover for themselves some of the relationships between temperature and behavior. They can observe what happens to the behavior of a goldfish when the temperature of the water in the aquarium is lowered; they can note the movement of insects that have been placed in a box that is heated at one end. In the study of light, however, we cannot expect young pupils to use the inductive process to arrive successfully at the wave theory of light. Thus, deductive and inductive methods of presenting material have been used both selectively and realistically in *Science for Tomorrow's World* to achieve a maximum challenge to pupils' intellectual curiosity.

The second basic principle we accept is that *the elementary school child should gradually build a structure of science approximating the structure developed by the scientist.* Sometimes, in an effort to simplify subject matter, teachers have introduced erroneous concepts on the supposition that these concepts were easier for the child to understand. One such teacher taught that "Some insects lay eggs that hatch into worms"; he did this because he thought that "larvae" was too difficult a word to introduce to his second-grade class. It is possible, of course, to teach such a concept without actually using the word for the concept. But most important is that *the concept be accurate.* The biologist puts worms into a phylum that is completely separate from the phylum for insects; to say that larvae are "worms" puts a mistaken emphasis upon unimportant similarities in the appearances of the larvae and worms. We believe that a selection of simple but significant concepts can be taught so that even the young child has some exposure to the main ideas that structure a particular field of science. We also believe that children should know of man's long and continuing struggle to structure his knowledge—of the wrong turns he has made at times, and of how difficult it is to give up erroneous concepts even in the face of their inefficacy. Children should know and experience the exploration of the unknown, and they should also attempt to search for coherence in the world around them. Only then will they gain a perspective of science as man's attempt to decipher the code of the universe.

We have emphasized repeatedly man's basic tendency toward equilibrium—his need to resolve cognitive disturbance by accepting those ideas that fit with reality. But, as the history of science so dramatically illustrates, there is at the same time a strong tendency to resist change, to cling to cherished notions. In teaching science, we must not present a picture of the scientist as a kind of superman who readily accepts evidence that contradicts his own way of thinking. Part of the subject matter of science is the history of science; studying the history helps pupils to see the scientist as a human being, one who has had to engage actively in the process of accommodating to new theories—a process as difficult for him as for all other men.

The third principle we accept is that *the acquisition of knowledge can enhance logical thinking when proper attention is paid to processes.* The child becomes more logical in his thinking when he acts upon the data he assimilates, putting two and two together, making analogies by a one-to-one correspondence between parts, seeing the implications of one action upon another, setting up alternative hypotheses ("It's either this or that"), excluding variables that check out to be irrelevant. An important part of the teacher's responsibility in teaching science is to help the child acquire mental processes for transforming data so that

inconsistencies in thinking can be eliminated and reasoning can become more logical.

In teaching elementary school science, much has been made of the scientist's sequential method of searching for truth—of observing, hypothesizing, testing, noting results, drawing conclusions. Each of these activities is an important scientific activity, but note that the scientist does not necessarily proceed step by step from one activity to the next. Thus, observation is part of *every* scientific activity; or, a scientist in the process of testing may observe that a certain phenomenon does not conform to what he thinks ought to be happening, and as a result he may start off on a new and perhaps more important track. The elementary science curriculum ought to describe the scientist's methods. But in order to ferret out contradictions, in order to make children "think like a scientist," we need to emphasize (1) logical thinking, (2) the habit of testing concepts, and (3) the checking of concepts against their consequences in experience. To teach children a pat process is not the answer; we will return to this point later in our discussion.

The child, the structure, the processes—these are the foundation stones of *Science for Tomorrow's World.* While we deal with structure and processes in succeeding sections, there is no separate section on the child; consideration of the learner is woven into every section.

THE STRUCTURE OF SUBJECT MATTER IN THE ELEMENTARY SCIENCE CURRICULUM

In building a curriculum, the first obvious question that we ask is, "What is considered important for children to learn in the field of science?" With man's knowledge expanding at a fantastic rate, it becomes increasingly necessary to exercise great selectivity in choosing the subject matter that is to be taught to children. For the past ten years, scientists and teachers have been working cooperatively on this problem to produce new science materials for both elementary and secondary schools.

Let us look at an area commonly included in elementary science curricula—Living Things. The majority of pupils in elementary school study living things, but what are the pupils expected to learn? Past curricula taught generalizations such as, "There are many different kinds of animals," "Pets are our animal friends," "Earthworms help to make the soil good for the farmer," "The toad has a tough, dry skin," and "The toad uses its forked tongue to catch insect pests." The difficulty with such facts is that they do not *explain*; they do not help the pupil to grasp the underlying *structure* of the science of living things. Such facts about natural phenomena give descriptions in only a general and superficial way.

In contrast, the present trend in science teaching is to emphasize *key concepts* rather than specific facts. Specific facts are included, but they are seen in relationship to the key concepts. Granted that the toad has a tough, dry skin; the scientist then asks, "What does such a skin *do* for the toad?" In answering this question, the scientist draws upon the key concept of *adaptation*—adaptation being the adjustment that an organism can make to a given set of conditions because the organism possesses certain structures that have survival value and that are passed on to offspring. Such a concept explains many phenomena, from the dry skin of the toad to the claws of the lobster.

Next the scientist asks, "How does it work?" For example, "How is the forked tongue of the toad adapted to the particular diet of the toad?" "What enables the bat to hunt at night?" "How are the eyes of the bat adapted to night flying?" These questions lead to another key concept—the interdependence of structure and function. Again, as with adaptation, this key concept explains many phenomena: The tongue of the toad is uniquely built for "lightning-quick" action in catching and holding onto flying insects; the eyes of nocturnal animals have more rods than do

the eyes of other animals, and so the nocturnal animals are able to use the available light to see in very dark places.

The question of, "How does it work?" in relation to living things eventually brings the investigator to the cell, the basic unit of life. The key concept with which he works here is that the cell can be compared to a factory where raw materials are processed according to chemical instructions inherent in the genes of the cell. The cell's finished products are released into the bloodstream to find their way to the appropriate part of the organism.

From "How does it work?" the scientist goes on to ask, "How did it come about?" The answer to this last question lies in the evolutionary principle that individual differences in the offspring of an animal are passed on to succeeding generations if the differences have survival value. Over millions of years, these differences have led to the enormous diversity of living things in existence today. For example, pupils can trace from a common ancestor the gradual evolution of separate families of dogs and cats. Such an activity is more intellectually exciting than merely learning the fact that "The dog is man's friend."

In the physical sciences also we can find a contrast between the "old" science and the "new" science taught to elementary school children. Let us take, for example, the topic of motion. In many programs, a pupil learns, "A wagon goes faster downhill because of gravity; gravity pulls things toward the center of the earth." But to tell a pupil that gravity makes something accelerate on a decline is only to give a *name* for the phenomenon; it does not really *explain* the phenomenon. For an explanation of any motion, the scientist turns to Newton's three laws. The scientist can predict from one of them that a constant force applied in the direction of the motion will make the object accelerate. This key concept of the effect of a constant force can be used over and over again—to explain why a bicycle will accelerate even though the rider pedals with the same force or why an object falls faster as it nears the ground.

The scientist, using another of Newton's laws, can also predict that for any action in one direction there is an equal and opposite reaction. Again we find that this key concept can be used over and over. The frog is capable of a broad jump of several feet, but only by pushing backward against the mud or sand from which it springs. An inflated balloon released in the air will push forward rapidly as the air inside the balloon jets out, demonstrating the principle of movement of a jet airplane.

THE CONCEPTUAL FRAMEWORK OF "SCIENCE FOR TOMORROW'S WORLD"

From a study of what scientists themselves consider important in science, the authors of this series have identified key concepts to serve as the conceptual framework for an elementary science curriculum. It is interesting to note that these concepts are limited in number; in only ten statements, presented in the section that follows, we have been able to encompass the principal achievements of all of science. These key concepts are the backbone of the science curriculum developed in this series. Each of the concepts has been broken down into elements and the elements arranged from the simple to the more complex, so that the structure of a discipline is gradually acquired by pupils as they progress through the grades. Examples of such sequential development follow.

1 *Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.*

Throughout his study of science in elementary school, the child ought to come to grips with the ques-

tion of what science is all about and how the scientist proceeds to carry out his work. To many children, science merely means such things as satellites going off into space, mysterious brews bubbling over Bunsen burners, or tiny forms of life being viewed under microscopes. The children identify conspicuous activities of some scientists as being science itself, erroneously viewing the purpose of the scientist as essentially practical—to make life easier, safer, and more livable for man.

How can we convey a different picture? How can we help the child to acquire a concept of science as a search for order in the universe? Even the young child is aware of events in the natural environment. He is aware of change—day changing into night, leaves falling and new leaves appearing, grass turning brown and then green again, weather changing, living things changing with age. But what the child is not aware of is that events happen in an orderly rather than in a haphazard, or chaotic, way. The child who first enters school is inclined to explain events by anthropomorphism, attributing to natural phenomena either a human knowledge or a human-like will to make things happen. Thus, grass turns green "because it wants to and because green is prettier," and birds fly south "because they know that winter is coming." The problem for the teacher is to encourage and help children to view science as an attempt to explain natural phenomena, not in terms of anthropomorphism, but in terms of certain fundamental natural laws.

There are several ways to accomplish this objective. The content of science itself helps. The primary school pupil studies tornadoes not as chaotic events but as the result of changes in air conditions. He finds out that a seesaw is balanced not because "the seesaw wants to," but because the *forces* on each side of the seesaw are balanced. Scientific explanations for familiar phenomena help the child appreciate science.

Emphasizing the key concepts that make up the structure of science is another way to help children to view science as a search for order in the universe. For example, the child who from the first grade has been exposed to basic concepts about the motion of objects tends to develop a conception of science as a search for basic laws. Such a conception is radically different from the conception of the child who continually interprets events in the world of nature in terms of their meaning for man only. A science curriculum that emphasizes such concepts as that some animals are useful to man conveys a very different idea of science from that conveyed by a curriculum that says that no two offspring of an animal are alike; differences passed on from generation to generation tend to accumulate, so that over millions of years a tremendous variety of living things has evolved on the earth ("Life on the Earth," Book 6).

Exposing a pupil to the "scientist's science" is one way of widening the child's appreciation of science. Another way is to include a historical perspective of science. In *Science for Tomorrow's World,* for example, as children find out how man's ideas of the solar system have changed over the centuries, the children come to view science as a questing for better answers. One "Pathfinders in Science" section in Book 3 illustrates how the genius of one man, Copernicus, caused an unwieldy concept of what is happening in the world of nature to be replaced by a more lawful concept—one that fitted the facts and explained the solar system more simply.

Still another way of conveying to pupils that science is a search for laws that explain events in the natural environment is to expose the children to the methods of science. Beginning with Book 3 of this series, and in each succeeding book, there is an introductory unit that conveys to pupils what the scientist tries to do and how he goes about his work. The child sees the importance of observation at every point. From observations of similar situations, he, like the scientist, tries to extract a kernel of knowledge, a principle that has wide application. The kernel is a

hypothesis only, for as the child comes to realize, a scientific principle is tentative; it may or may not explain new observations, and so ultimately it may have to be discarded for a point of view that can deal more successfully with the phenomena to be understood. Over and over again, the pupil finds out how man has changed his viewpoint on many things—the nature of changes on the surface of the earth (Book 3), the movement of the planets in the solar system (Books 3 and 6), what light really is (Books 4 and 6), what all matter consists of (Books 4, 5, and 6), and how magnetism and electricity are related (Book 6).

2 *Lawful change is characteristic of events in the natural environment; although living things tend to produce living things like themselves, over millions of years the earth and living things on the earth have changed, and diversified forms of life have evolved.*

As we have pointed out, even the young child is conscious of changes in the natural environment, but he lacks, as did man for thousands of years, the historical perspective. The young child does not realize the cumulative effect of the small changes that he sees going on about him. Waters may muddy as they tear away at the banks of a brook or a creek, but the child does not see that a Grand Canyon is ultimately produced by such forces. He hears of a new breed of insect that is immune to DDT, but he does not see the same principle at work producing the tremendous variety of living things in existence today.

In this series, throughout each of the books, the child is exposed to the concept of orderly change. This concept of orderly change over an extended period of time begins in Book 2 with the account of the life cycle of the moth. In Book 3, the pupil is introduced to the notion of changes in living things and in the surface of the earth, while in later grades these changes are spelled out in considerably more detail. For example, in the unit entitled "How Animals Behave" (Book 6), the reader finds out how two separate families, dogs and cats, evolved gradually from a common ancestor.

3 *To find order in the natural environment, the scientist seeks basic units that can be put together in an almost infinite variety of ways; the cell and the atom are examples of such units.*

We begin the development of this concept by helping the young pupil to discover the fact that, like all other substances, air takes up space. In fact, the door of an "empty" car may be hard to close because of the pressure of air inside the car. The child can find out more about the "stuff" of which air is made by warming the air in a closed glass container and watching the beads of water collect on the cover. From such experiences he discovers that matter can exist in particles that are too small to be seen with the naked eye—particles such as the individual molecules of water in a cloud of water vapor or the individual cells that make up the pupil's body. Beginning in grade 4, he can use a magnifying glass to make some very small things visible and to examine actual cells or pictures of cells with a microscope. His knowledge of the structure of the cell is expanded, bit by bit, and the bits are related more fully in a separate unit on cells in Book 5. Similarly, readiness for the study of the atom is built throughout the grades, culminating in the chemistry unit in Book 5.

4 *All objects in the universe and all particles of matter are constantly in motion; man has discovered and stated the laws governing their motion.*

The study of the basic science of motion begins in Book 1. Here the pupil learns that things do not start to move by themselves: A push or pull, called a *force,* is necessary to make a thing move. As the pupil advances to Book 6, page 106, he will learn the formal

name for the principle introduced here—the principle of inertia—but for the first grade, the concept is developed without use of a formal name. The second grade pupil learns more about the laws of motion: Once an object is moving, it continues to move in the same direction and at the same speed, unless another force acts upon it; for example, a passenger in a car continues to move forward when the car stops suddenly, unless a force in the opposite direction is applied by an opposing object, such as a seat belt. In Book 2, he also discovers that a steady force on an object in motion will make the object speed up. In Book 5, the pupil delves into the discoveries of Newton and learns that an object shot off into space has two kinds of force acting on it—a forward force, causing the object to continue in the same path and at the same speed at which it started (a review of the concept taught in Book 2), and a downward force, resulting from the force of gravity (a review of a concept taught in Book 3). The effect of these two kinds of force working on the object is that the object follows a curved path, since the constant forward force of the object is continually being deflected by the constant force of gravity.

The motions of heavenly bodies and the laws governing those motions are also presented in step-by-step fashion. The primary grade pupil finds out how movements of the earth in relation to the sun cause daily and seasonal changes, while the intermediate grade child studies the differing theories of Ptolemy and Copernicus to better understand the motions in the solar system. The movement of stars as a navigational aid is explained in Book 8, and the meaning and use of time zones is included in Book 9.

Not only are the motions of the largest objects in the universe covered by this key concept, but so also are the motions of the smallest particles. In grade 4, the pupil is first introduced to the concept of molecules and their motion in moving air. The grade 5 pupil learns that the state of matter—solid, liquid, or gas—is determined by the motion of molecules, and the grade 6 pupil finds out about the rotations of electrons within the atom.

The study of motion is not confined to the physical sciences. As the pupil studies the circulation of blood (Books 3 and 5), the transportation systems of plants (Books 4 and 6), and the movement of materials in and out of cells (Books 3, 4, 5, and 6), he has the opportunity to apply physical principles (such as the concept of diffusion) to the functioning of living organisms.

5 *The motion of particles helps to explain such phenomena as heat, light, electricity, magnetism, and chemical change.*

To the elementary school pupil, it may seem unreal that the particles of matter in all objects are constantly in motion. It may be hard for him to think of his desk, for example, as being made up of moving particles. In his desk, as in any solid, the average position of the particles is fixed; they cannot move past one another, although they can vibrate. But if the pupil rubs his fist hard and fast over the surface of the desk, the spot warms up as the particles move more rapidly and farther apart. He can infer from certain experiences—the transfer of heat from warm things to cold things, the expansion of hot objects and the contraction of cold objects, the heating up of a wire carrying an electric current, the growing of a crystal in solution, the process of chemical change—that particles *do* exist and that they must be in motion to produce the phenomena he is observing. In fact, it is *only* as the pupil becomes aware of the motion of molecules that he can understand such phenomena as heat, light, electricity, magnetism, and chemical change.

Readiness for the concept of molecular activity begins in the primary grades. In Book 1, the child discovers that there is a relationship between temperature and rate of evaporation. In Book 2, the effect of heat upon volume of gases and liquids is introduced,

as is the relationship of heat to changes in state of matter from solid to liquid to gas. In Book 4, the pupil finds out about electron motion in current electricity, and in Books 5 and 6, he learns about the structure of the atom and the concept of the motion of particles applied explicitly to heat, light, electricity, magnetism, and chemical change.

6 *There is a basic tendency toward stability or equilibrium in the universe; thus, energy and matter may be transformed, but the sum total of matter and energy is conserved.*

Beginning with Book 2, pupils get their first exposure to one of the key concepts of science—conservation of matter. At this level, pupils discover that the matter (a ball of cookie dough) remains the same even though the matter may be transformed in appearance (made into cookies). In grade 3, in connection with a study of changes on the earth, pupils find out that while a river may cut deeper and deeper into its bed, carrying away soil in the process, the soil that is carried away does not dissolve into nothingness in the water. The soil may be transported and dropped at the river's mouth, but it is not lost. *The total amount of matter in the system at any point in the transformation remains the same.*

Similarly, the pupil learns that energy can be transformed. The primary child can understand that energy in the form of gasoline in the tank of a car must be transformed by burning if the car is to be able to move. In the same way, energy is produced in the body when food is burned during the digestive process. Furthermore, there is a relationship between the amount of energy available to do work and the intake of fuel or food. A car without gas will stop, and a hungry person soon becomes tired. Such commonplace, easily understood examples provide the basis for understanding the concept that although man may make transformations in a system, the equation for the system will balance at the end of the transformation.

7 *When equilibrium is upset in organism-environment interactions, regulatory mechanisms go to work to restore equilibrium.*

This key concept involves the basic tendency of organisms to strive for equilibrium. Temperature regulation is one of the best-known examples. In human beings, equilibrium with respect to body temperature exists at about 98.6° F. Evaporation of water from any surface has a cooling effect. When the body becomes overheated, we perspire, and equilibrium is restored; when the body is chilled, goose bumps on the skin reduce the exposure of blood vessels to the cold, and body heat is conserved. When equilibrium in body temperature is restored, the goose bumps subside.

From the simplest plants and animals to the most complex, we can find illustrations of how certain mechanisms go to work to restore equilibrium when it has been upset. These mechanisms serve the function of helping the organism to survive.

8 *There is a relationship between structure and function; the structure of parts of living organisms determines the function of those parts.*

In the development of this key concept, we use the same approach as for the other key concepts in *Science for Tomorrow's World*. We begin in the primary grades with examples of the relationship between structure and function. Even the first grade pupil can observe in real life or in pictures that not all birds can scoop up fish from the sea or dig for insects in the trunk of a tree. Observations lead to the concept that the beak structure of a bird enables the bird to obtain food in a special way—a concept that leads to further observation and discovery of more specifics. For the older pupil, the relationship is stated explicitly. First

the pupil is exposed to many examples: in the unit on "How Animals Behave" (Book 6), there is a detailed discussion of the sensory receptors of animals—from the planarian to the fish. The remarkable chemical receptors of the male fish not only enable it to detect male-female differences in other fish of the same species, but also to detect when the female is ready to mate. Even the simple planarian, as pupils can observe, uses chemical receptors on each side of its head to detect food, waving the receptors from side to side to find the greatest source of stimulation. Thus, the key concept is stated for the pupils: "The way in which sensory receptors are made (their structure) is related to how they work." The pupils are then asked to apply the concept to any independent observations they make of animals not discussed in the text.

9 *The scientist has developed measures of space, time, and matter so that he can communicate explanations that are reproducible and make predictions about events in the natural environment.*

That there is a relationship between mathematics and science is common knowledge. The student, however, should be encouraged to deal with the relationship well before he has to use calculus in high school physics; as is true for other key concepts in the basic structure of science, readiness should begin in the primary grades.

The first step in a pupil's appreciation of the relationship between mathematics and science is to have him quantify his data. This can begin in the first grade. A pupil learns that a seesaw is in equilibrium when the same number of books of equal size and weight are placed equidistant on both sides of the fulcrum. Through experience, he learns to coordinate weight and distance in a systematic way; a large weight at a small distance on one side balances a small weight at a large distance on the other side. Quantification of data extends to record keeping, and *record keeping involving two variables is encouraged.* In Book 2, for example, pupils learn to keep a record of the temperatures of jars of water that have been covered with materials of different colors. The children also learn to record the length of time that the jars are kept in the sun. Thus, both temperature *and* time are recorded. The important mathematical concept of *function*—that a change in one variable can result from a change in another—receives reinforcement here. Record keeping in the form of a double-entry table is encouraged. Use of such tables need not be postponed until the upper grades; even a pupil in the second grade can learn to read a double-entry table, as well as to classify certain objects in terms of size and weight:

<table>
<tr><th></th><th></th><th colspan="2">SIZE</th></tr>
<tr><th></th><th></th><th>Small</th><th>Large</th></tr>
<tr><th rowspan="2">WEIGHT</th><th>Light</th><td>| |</td><td>|</td></tr>
<tr><th>Heavy</th><td>| | |</td><td>| |</td></tr>
</table>

This chart, for example, shows that of the objects to be classified, two are small and light, one is large and light, three are small and heavy, and two are large and heavy.

Many experiences of this kind help the pupil to develop the mental agility needed to deal with concepts involving two variables. Thus, in *Science for Tomorrow's World, speed* is defined in terms of distance covered in a certain length of time; *density* is defined by the amount of matter contained in a given volume of space; *force* is defined by the relationship between mass and acceleration. The pupil who can see such concepts on a graph is clearly better equipped to deal with these concepts. He can think more understand-

ingly about them because his mind has been trained to think in this fashion during the period of his elementary school years.

Two units in particular in *Science for Tomorrow's World* are devoted to the relationship between mathematics and science. Book 5 contains a unit on "Testing Ideas," which introduces pupils to probability theory; an entire unit in Book 6 is devoted to developing the concepts of "a unit of measurement" and the "meaning and methods of measuring space, time, and matter."

10 *Man has changed and continues to change the natural environment; but because he is often ignorant of long-range consequences, his actions may have harmful effects for himself and for other living organisms.*

One of the basic problems facing modern man is that of maintaining a dynamic equilibrium with his environment. It is commonplace today to point out the rapid pace at which man is depleting elements of his environment. Water and air pollution, overpopulation, and improper use of chemicals are only a few of the many problems that man must solve if he is to function at an optimum level in the world of nature. Many such problems arise because man does not foresee the long-range consequences of his actions. For example, no one was able to predict that the wholesale use of DDT for the spraying of insects would result in the killing of many birds, or that the clam and oyster industries along parts of the Atlantic seaboard would be threatened by the dumping of wastes into coastal waters. Man must begin to develop foresight if he is to survive; he must become more concerned with the *total* natural environment.

There are moral and philosophical, as well as scientific, considerations involved in the above key concept about man and the natural environment, and obviously the elementary school child is not equipped to deal with them. But even a second grade pupil is capable of understanding that living things need air, water, food, and proper temperatures to survive. He can find out by experimentation what happens to plants deprived of one or more of these essentials of life. Third grade children can learn what is needed to make safe drinking water and, also, how man has contributed to water pollution. By the fifth and sixth grades, pupils are ready for a study in greater depth of some of the many other problems of man's own making ("Life on the Earth," Book 6). Of course, pupils cannot arrive at solutions to these problems, but the teacher can create a climate of opinion so that in later years, as adults, these same pupils will be more aware of both the necessity of managing natural resources with greater intelligence and the long and thorough pilot studies that are needed before any new products and solutions can receive full-scale application.

The ten key concepts that we have discussed form the structure of science in *The Macmillan Science Series*. Two things are worth emphasizing about these key concepts. The first is that all of the structure of science can be set forth in *so short a list;* the second is that there is considerable agreement among scientists that these ten key concepts actually *do structure science*. The reader may be interested in comparing the key concepts basic to *The Macmillan Science Series* with the set of propositions published by the National Science Teachers Association. These propositions are the result of extensive studies concerning the question of what to teach elementary school children. These studies were carried out by scientists and teachers working together. The following list, quoted from *Theory into Action,* published by the National Science Teachers Association, Washington, D.C., (1964) represents seven conceptual schemes and five major items in the process of science that were tentatively defined by the NSTA Committee as constituting the structure of science.

1. All matter is composed of units called fundamental particles; under certain conditions, these particles can be transformed into energy, and vice versa.

2. Matter exists in the form of units which can be classified into hierarchies of organizational levels.

3. The behavior of matter in the universe can be described on a statistical basis.

4. Units of matter interact. All ordinary interactions are either electromagnetic, gravitational, or nuclear forces.

5. All interacting units of matter tend toward equilibrium states in which the energy content . . . is at a minimum and the energy distribution . . . is most random. In the process of attaining equilibrium, energy transformations or matter transformations or matter-energy transformations occur. Nevertheless, the sum of energy and matter in the universe remains constant.

6. One of the forms of energy is the motion of units of matter. Such motion is responsible for heat and temperature and for the states of matter: solid, liquid, and gas.

7. All matter exists in time and space, and, since interactions occur among its units, matter is subject in some degree to changes with time. Such changes may occur at various rates and in various patterns.

The following are the five major items identified as essential to the process of science:

1. Science proceeds on the assumption, based on centuries of experience, that the universe is not capricious.

2. Scientific knowledge is based on observations of samples of matter that are accessible to public investigation in contrast to purely private inspection.

3. Science proceeds in piecemeal manner, even though it also aims at achieving a systematic and comprehensive understanding of various sectors or aspects of nature.

4. Science is not, and will probably never be, a finished enterprise, and there remains very much more to be discovered about how things in the universe behave and how they are interrelated.

5. Measurement is an important feature of most branches of modern science because the formulation as well as the establishment of laws is facilitated through the development of quantitative distinctions.

SEQUENCE IN THE SCIENCE CURRICULUM

The task of curriculum building in science includes a number of steps, the first of which is the identification of the key concepts that together add up to an understanding of the meaning of science. These key concepts have already been discussed. We have included in *Science for Tomorrow's World,* at the various grade levels, illustrations of these key concepts so that the children may see them materialized in learning situations. However, it is also essential that each key concept systematically be broken down into smaller pieces of relevant information. These smaller pieces must be arranged in sequential order from simple to the more complex, and the pieces must be assigned to proper grade levels.

A well-constructed development of concepts, taught in "spiral fashion" throughout the elementary school years (reinforcing every other year or two what has been learned earlier, and then advancing to a higher level of understanding) is essential for a meaningful understanding of science. The charts on the next two pages illustrate the sequence that has been developed in *Science for Tomorrow's World.*

1 Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

2 Lawful change is characteristic of events in the natural environment; although living things tend to produce living things like themselves, over millions of years the earth and living things on the earth have changed, and diversified forms of life have evolved.

3 To find order in the natural environment, the scientist seeks basic units that can be put together in an almost infinite variety of ways; the cell and the atom are examples of such units.

4 All objects in the universe and all particles of matter are constantly in motion; man has discovered and stated the laws governing their motion.

5 The motion of particles helps to explain such phenomena as heat, light, electricity, magnetism, and chemical change.

BOOKS IN WHICH KEY CONCEPTS ARE DEVELOPED AND THE NUMBER OF UNITS IN EACH BOOK DEALING WITH THE CONCEPT

KEY CONCEPTS	*BOOKS*						*TOTAL UNITS*
	1 (6)*	2 (6)	3 (6)	4 (9)	5 (9)	6 (9)	
1	6	6	6	9	9	9	45
2	1	3	1	1	1	2	9
3	0	1	1	2	3	5	12
4	1	3	1	1	3	3	12
5	3	3	0	1	2	3	12
6	2	3	1	5	4	3	18
7	1	3	1	1	2	2	10
8	3	2	1	2	3	2	13
9	1	2	0	2	4	7	16
10	0	0	1	0	1	1	3
Total Concepts	8	9	8	9	10	10	

** Number of units in the book*

6 There is a basic tendency toward stability or equilibrium in the universe; thus, energy and matter may be transformed, but the sum total of matter and energy is conserved.

7 When equilibrium is upset in organism-environment interactions, regulatory mechanisms go to work to restore equilibrium.

8 There is a relationship between structure and function; the structure of parts of living organisms determines the function of those parts.

9 The scientist has developed measures of space, time, and matter so that he can communicate explanations that are reproducible and make predictions about events in the natural environment.

10 Man has changed and continues to change the natural environment; but because he is often ignorant of long-range consequences, his actions may have harmful effects for himself and for other living organisms.

UNITS IN WHICH KEY CONCEPTS ARE INTRODUCED IN BOOK 5

KEY CONCEPTS	*UNITS*									*TOTAL UNITS*
	1	2	3	4	5	6	7	8	9	
1	X	X	X	X	X	X	X	X	X	9
2									X	1
3		X	X			X				3
4						X	X	X		3
5						X	X			2
6						X	X	X	X	4
7				X	X					2
8		X	X	X						3
9	X					X	X	X		4
10									X	1
Total Concepts	2	3	3	3	2	6	5	4	4	

Once major generalizations have been identified and the flow of ideas from grade to grade is roughed out, it then becomes necessary to plan teaching units suitable to the developmental level of the child. Each unit covers a period of instruction varying in length from two to four weeks. Such an arrangement of text material in eight or nine major blocks of subject matter permits more efficient teaching and learning than when a text is divided into thirty chapters with a different topic for each chapter. Under the unit arrangement the teacher does not shift gears every few days, having to gather equipment with each shift as well as having to reorient pupils' thinking.

The Table of Contents, which lists the titles of each unit of the first six books, is reproduced in Part IV. By looking at the titles, a teacher can tell at a glance whether or not the pupils have had any previous exposure to a particular area. The sequence charts on page 20 will reveal the amount and quality of the exposure.

An examination of the titles reveals some immediately familiar areas in science education. Such topics as "Probing the Atmosphere," "Living Things—Green Plants," "Light and Sight," and "Using Electricity" have been part of the elementary science curriculum for many years; although, as has already been pointed out, the specifics taught under each topic have often been different. In studying about light, for example, the children do not learn only that light is made up of particles traveling in a straight line; the children also learn that light particles travel in a wave motion, similar to the motion of a water wave when a pebble is dropped into a pond. Elements of key concepts are built into the topics, so that, although the topic itself is not new to the curriculum, each element becomes a vehicle for teaching the structure of science from a contemporary point of view.

Some topics reveal new developments in the sciences. Conservation of water resources and problems of air pollution are being emphasized today as much as conservation of soil was emphasized a few decades ago. This trend is reflected in the unit "Life on the Earth" (Book 6). Oceanography, for another example, is a rapidly expanding field of knowledge. With so many basic scientific data now known about life in the sea, ocean currents, salinity, and the geology of the ocean floor, the study of oceanography well deserves a place in the elementary science curriculum. The picture story "Probing the Oceans" (Book 5) highlights the work of oceanographers at the Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, and will stimulate interest in this exciting field. Similarly, the stepped-up pace of man's exploration of space leads not only to the inclusion of space travel, but also to an increased emphasis on the science of astronomy.

PART II: HOW CHILDREN ACQUIRE SCIENCE KNOWLEDGE: A DEVELOPMENTAL APPROACH

For any discussion of how children acquire science knowledge, educators today lean heavily on the work of Jean Piaget, a Swiss psychologist who has been working with his collaborators in Geneva for over 40 years on the study of cognitive processes. Cognitive processes are those intellective processes by which knowledge is acquired. Piaget has developed a theory of how these processes begin in infancy and how they change as the child matures. His theory is a developmental one; characteristics of children's thinking are described in age-related stages. On the basis of Piaget's theory, we can predict the thought processes of children within a certain age range. There are, of course, individual differences in maturity of thinking; some children, because of heredity and experience, are more advanced than others; but, according to Piaget, the thinking of all children tends to go through the same stages and, on the average, when they are at the same age.

Piaget's description of developmental stages in children's thinking has generated a tremendous amount of research on both sides of the Atlantic. Many investigators have worked on the problem of whether or not his theory is a valid one. The conclusion to date is affirmative; the same stages characterize the thinking of Swiss, Norwegian, English, French, Canadian, and American children. In fact, when the tests developed by Piaget and his chief collaborator, Barbel Inhelder, are given to subjects in different countries, investigators report that translations show almost identical wording in children's answers. American cognitive psychologists, like Jerome Bruner of Harvard University, have extended and refined Piaget's theory, so that today we have a well-constructed and validated model of the thinking processes involved in the acquisition of knowledge. An understanding of how children acquire knowledge is basic to improvement of the teaching-learning process; we cannot help children to become better thinkers unless we know something about thinking processes and how they change with age, nor can we construct effective textbooks without taking into account developmental changes in cognition.

How can we put the findings of Piaget and other cognitive psychologists to work in teaching science? As we have pointed out, one of the aims of science educators is to teach the methods of science, to teach the child to use the same logical processes of thinking that a scientist uses to solve problems. For too long,

teaching the methods of science has meant teaching children to follow a formula: Observe; Hypothesize; Test; Evaluate. The formula is still valid, but it is not enough. The child in primary grades *does* observe, but, as we know from Piaget's work, he is likely to focus on the wrong property of an object or event as he observes. Similarly, the pupil in intermediate grades *does* hypothesize, but if he picks out the wrong variable for testing, he doesn't know what to do next. Nor does he know what to do next if he gets positive results from testing, for he doesn't know the specifics of "Evaluate"; he doesn't know, for example, that he must test for *exclusion* of other variables.

In developing *Science for Tomorrow's World* we set as goals that the texts should not only help the child build a structure of science (the scientist's science), but should also develop logical thought processes. We believe that the study of science can help children become better thinkers, but that there must be deliberate planning to achieve this end; the improvement of thinking processes should not be left to chance. Guided by the discoveries of Piaget and other cognitive psychologists, we have used content, activities, and illustrations in the series to foster logical thinking. We will now discuss what is known about the normal course of intellective development, before discussing how that knowledge can be put to use in teaching science.

For Piaget the development of intelligence begins as early as the cradle stage and continues through stages from birth to maturity. The first stage Piaget calls the sensorimotor. The infant comes into the world with two kinds of reflexes: those, such as the knee-jerk, that are not altered by experience, and others, such as grasping and sucking, that are modified as the infant exercises them. The modification occurs through assimilation and accommodation. The infant, for example, accommodates the grasping reflex to the shape of the object to be grasped, curving his fingers one way to grasp a long narrow object, and in a different way to grasp a ring. During the first 18 months, the infant carries on countless transactions involving space, time, matter, and causality which build and reshape developing mental structures. Witness what happens with respect to the notion of permanence of object. To the 2-month-old infant, the game of peek-a-boo is meaningless; for him an object ceases to exist when it disappears from view, and out-of-sight is out-of-mind. Later in the first year of life, the infant knows that an object continues to exist and delights in searching for it when it is hidden. He "knows," not in words, but in his sensorimotor system, in much the same way that we may "know" how to find our way through a still strange building the second time. For Piaget, sensorimotor intelligence is the intelligence of action. The infant must first carry out displacements in his *actions,* rather than in thought. If an object is hidden first in one place and then another while the toddler looks on, he must carry on a physical search for that object, going from cushion to cushion; he cannot sit back and point triumphantly to where the object is, for he cannot visualize its displacement in his mind. However, by 18 months the child is capable of representation, of imagining the environment other than as he directly perceives it.

The next stage, the *preoperational,* extends from 18 months, roughly, to about 7 years. It is in this stage that we find most first and second grade children—and, of course, some children even older than 7 years. This stage is called "preoperational" because the child does not use logical operations in his thinking. We can summarize the characteristics of pupils' thinking at this level as follows:

1. *The child is perceptually oriented; he makes judgments in terms of how things look to him.* When given a problem in which two lines of ten segmented sticks of equal length are laid out in parallel rows, he will see that both lines are equal. He will see that two dolls, walking along these paths, would each walk the

same total distance. But if one of the rows is rearranged in a zig-zag fashion, when the child is again asked if each doll takes as long a walk as the other, the child says, "No." Even when he counts the segments, he denies equality; the child does not see that there is a logical necessity in which ten must equal ten. Piaget has shown that this same type of perceptual judgment enters into the preoperational child's thinking about space, time, number, and causality. It is only as the child goes beyond his perceptions to perform displacements upon the data in his mind (for example, visualizing the second row of sticks straightened out again) that conservation appears.

2. *The child centers on one variable only, usually the variable that stands out visually; he lacks the ability to coordinate variables.* For example, a kindergarten child is pouring juice into paper cups. The standard-size cups run out, and the teacher substitutes some that are much higher but are also smaller in diameter. As the children drink their juice, several comment on the fact that Jimmy, Eddie, and Danny have more juice. Why? Because those children have cups that are taller. The dimension of height, not width, stands out. The child's thinking is rigid; he does not perform operations on what he sees. Later he will reason that "higher than" is compensated for by "skinnier than," and that both kinds of cups may hold the same amount of juice. This ability to see reciprocal changes in two sets of data is an important logical tool available to older children but not to the preoperational child.

3. *The child has difficulty in realizing that an object can possess more than one property, and that multiple classifications are possible.* It is hard for the child to see that one can live in Los Angeles and in California at the same time, that a bird is also an animal, and that, since there are animals other than birds, there are logically *more* animals in the world than there are birds. The operation of combining elements to form a whole and then seeing a part in relation to the whole has not as yet developed, and so hierarchical relationships cannot be mastered.

So far, this consideration of preoperational thinking has been largely negative. We have seen that the child lacks the ability to combine parts into a whole, to put parts together in different ways, and to reverse processes. What, then, can the child do? The development of logical processes is not at a standstill during this period; there are some positive accomplishments. We see, for example, the rudiments of classification: the child can make collections of things on the basis of some criterion; he can also shift that criterion. Thus if we present a kindergarten child with a collection of pink and blue squares and circles, some large and some small, and ask him to sort them into two piles with those in each pile being alike in some way, he can usually make two different collections on the bases of color and shape (a few children discover the third criterion of size). Such an ability, of course, is essential to the formation of classes and eventually of a hierarchy of classes.

The child is also beginning to arrange things in a series. He can compare two members of a set when they are in a consecutive order; he knows that Tuesday comes after Monday. But since Friday comes after Tuesday, which is after Monday, does Friday also come after Monday? This operation, involving seeing logical relations between things or events that are arranged in a series, is not yet possible to the preoperational child, but experiences with seriation are preparatory to the development of such operations. The "inching up" that an older pupil does in trying to establish equilibrium between two parts of a physical system (add a little to one side; then add a little to the other) is an example of a more sophisticated use of seriation.

Between 7 and 11 years of age on the average,

as the child assimilates information from his actions and accommodates mental structures to the new information, thinking processes change. The child abandons his perceptual judgments and thought takes on certain logical properties. Piaget calls this stage the stage of *concrete operations,* because, while the child uses logical operations, the content of his thinking is concrete rather than abstract. One of the mental operations that develops is that of combining elements; the child begins to put two and two together figuratively as well as literally. He uses this combining operation to discover (though not until toward the end of this stage) that a substance like sugar added to water will make the water level rise, and that the water level will stay up even after the sugar dissolves. It dawns on the pupil that matter combined with matter produces more matter, that matter doesn't disappear into nothingness.

Another property of logical thought is that elements of a whole can be associated in various ways without changing the total. Thus, in the problem of the segmented sticks, the segments can be "associated" in a straight line or zig-zag line, but the total distance of the path to be covered remains the same, or is conserved. And in studying science, the pupil can use the associative operation to discover how to keep a system in equilibrium—how, for example, when a muscle is flexed, it becomes shorter but thicker; when relaxed, it is longer but thinner. In each case, the total amount of muscle remains the same; the amount of matter is conserved, though its shape is changed.

A third property of logical thought is that of identity. The identity operation is basically a null operation; the child can mentally cancel out the effects of any operation by combining it with its opposite. He uses such an identity operation to reason that the effects of adding a force to one side of a balanced tug-of-war can be canceled out by adding a force to the other side (at the preoperational stage, he could solve the problem only by taking away the extra force that had been added). The pupil can also reason, as he thinks about a flexed muscle, that, since nothing has been added to the muscle and nothing has been taken away, then quantity of matter is identical before and after the flexing. An extension of the identity operation is the one-to-one correspondence a pupil carries on to establish identity between two sets. Is the spider an insect? The pupil must compare each characteristic in the set of insect characteristics with each in the spider set, on a one-to-one basis, to answer the question.

Of all of the properties of logical thinking, one of the most critical to develop is that of reversibility. Every change that the mind makes upon sensory data is reversible. The child can mentally rearrange the sticks in the zig-zag line, putting them back the way they were, to see that length is conserved. Similarly, a pupil can solve the problem of whether matter in a total system is conserved when a river carries away soil and deposits it in the river delta by reversing the depositing process. (See Book 3, Unit 3.)

A good deal of the research of Piaget and Inhelder on how children think about problems has centered on conservation problems in which matter, weight, or volume is conserved with a change in form. Results show that children achieve conservation during the stage of concrete operations, but that some conservation problems are easier than others. Conservation of length (the segmented sticks) appears first, followed in turn by conservation of matter (pouring sand into containers of different shapes) and conservation of weight. Conservation of volume (dissolution of sugar in water) is most difficult, appearing at about 11 years.

The operations described above characterize the thought processes of the child during the elementary school years, but beginning at about 12 years, there are further changes that occur in modes of thinking. Thinking is less tied to the concrete and becomes more abstract and formal. Piaget describes it as *proposi-*

tional thinking. The pupil can state propositions in terms of the variables he has identified and can then systematically combine the propositions so as to test all possible combinations. To reveal thinking processes, a pupil is presented in one of Piaget's tests with four flasks containing colorless, odorless liquids that look exactly the same, plus a bottle containing potassium iodide (not identified for him). He is shown that a few drops from the bottle can turn the proper (but unknown to him) mixture of liquids yellow, and he is asked to reproduce the process. If the pupil is at the formal stage of thought, his statements will reveal certain characteristics of thinking not found in younger children. For example, he will say, "If this stuff in the bottle is plain water, then when I put it with a mixture from the first and second flasks, it shouldn't make them turn yellow." In effect he is stating a hypothesis for testing, "If it's water, it wouldn't do this," or that one statement logically implies another. At the concrete stage, the pupil says, "I'll put this and this together and see what happens."

There are four ways in which propositions can be combined. We can combine by conjunction, as when we say, "It's got to be this *and* this"; by disjunction: "It's got to be this or this"; by negation: "It's neither this nor this"; and by implication: "If it's this, then this will be true." Let's suppose, for example, that a sixth grade child is interested in the problem of what attracts certain insects to flowers; two possibilities are design and color. How to combine the two? At the formal stage of thinking, the learner can systematically test all the possibilities by asking:

Is it color and not design?
If it's not color, then is it design?
Is it design and color?
Is it neither?

Each of these questions must next be stated as a hypothesis for testing. The question, "Is it color and not design?" must be restated as the hypothesis, "If it's color and not design, then when we present both stimuli (which are specified) to the insect, we ought to attract more insects to the color." But following the checking out of that hypothesis, if color "works," the pupil must then ask, "If it's color, is it any color? Does yellow work as well as red? Do fluorescent colors work better than nonfluorescent? If color red is equal to color yellow, the number of insects attracted to the stimuli should be the same." The outstanding characteristic of thought at the formal stage is the way in which the mind can combine propositions, going back and forth with lightning-like speed, and then stating what the combination implies in the way of experimental outcome. This mode of thinking begins to appear in bright children even before they leave elementary school.

BUILDING A SCIENCE SERIES TO FOSTER LOGICAL THINKING

The developmental picture we have described has implications for building a science series to foster logical thinking, as we shall see. However, it should be pointed out here that cognitive psychologists have made contributions other than the developmental picture. Piaget and Inhelder have given us insight into the misconceptions about science that children acquire, so that we can plan remedial activities. Bruner has described the process of concept building, a process that begins with a sensorimotor experience, proceeds to a step where a mental image is important, and then is completed at the symbolic level, where verbal understanding is accomplished. Aspects of cognitive theory other than the developmental picture have been considered in building our science series.

Implications of Cognitive Theory for Content Selection and Grade Placement

In building a science series, there must be a rationale for the selection and grade placement of sub-

ject matter. Part of the rationale is derived from scientists' analysis of what is important in science; we have selected for the content in this series the "scientist's science," ordered in terms of difficulty of concepts. Part of the rationale is derived, also, from what we know about the child. If the study of science is to improve thinking processes as the pupil acquires content, strategy for improvement must be based on what is known of the normal course of intellective development. In our discussion thus far, we have described the *normal course,* not the potential; it is with the norm that we start to accelerate development, for American educators are rarely interested in maintaining the status quo in achievement levels. Knowing the characteristics of preoperational thought, we selected content for the primary books in this series that will help the child overcome preoperational deficiencies and facilitate development of those properties of logical thought that appear in the stage of concrete operations. Knowing how the child thinks at the stage of concrete operations, we selected content for the middle grades to strengthen logical operations and advance the onset of propositional thinking. As previously stated, we take the position in this series that the development of the highest mental processes should not be left to chance; the school should foster logical thinking in every way possible, and the study of science offers unique opportunities to do this.

Some examples at this point may help to clarify our strategy. Particularly in the first two books, we present learning situations to help the child overcome his tendency to make perceptual judgments and to center on one variable. In Book 1, for example, the pupil is helped to discover that *both* weight at each end *and* distance from the fulcrum must be considered in balancing the seesaw; centering on the weight variable is not enough. In Book 2, the young reader has experiences in *coordinating* two variables; as he pours sand into containers of different shapes, he learns that "higher than" is compensated for by "skinnier than," so that quantity of matter is conserved. He is also given practice in identifying more than one property in classification problems; he discovers that sounds vary in *both* volume and pitch, and he works out with the teacher a 2 x 2 table (see page 4) to visualize the classification of the sounds to which he is listening.

But what of pupils in the first two grades whose thinking has advanced beyond the preoperational level? For such pupils, logical operations should be made explicit by the teacher so that their use, which may be only intuitive at first, will be strengthened. And the teacher, knowing the logical operations that appear in the average child 7 years old, can make every effort in all of her teaching to strengthen such thinking processes as they appear in pupils in the first two grades.

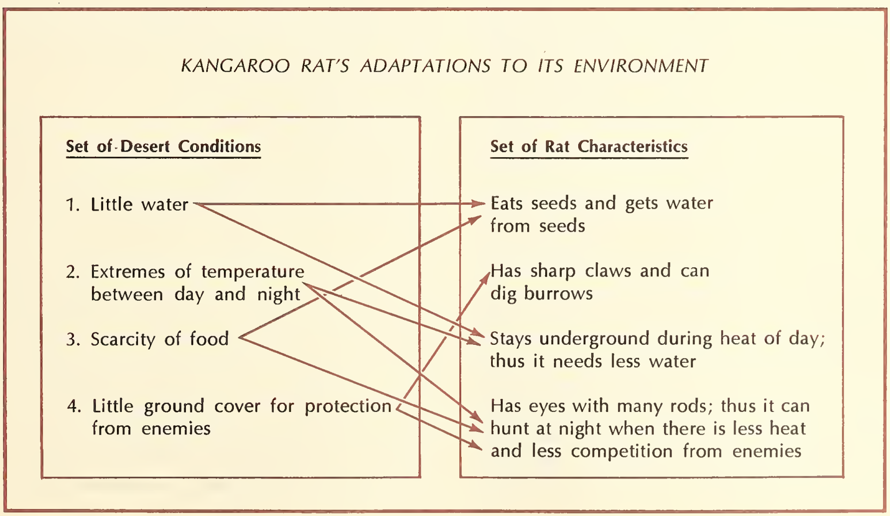
In Books 3, 4, and 5 there is increased emphasis on developing in the pupil these logical operations—combining elements, associating elements in different ways, establishing identity between elements, and reversing an operation—that characterize the stage of concrete operations (normally 7–11 years). There is considerable work, particularly in Books 3 and 4, on classification skills. Such skills began in Book 2, when a pupil learned to describe a specimen by more than one characteristic and then, to identify the specimen as either a butterfly or moth, to make a one-to-one correspondence between the characteristics of the specimen and those of the butterfly or moth. In Book 4, Unit 4, skills become more complex as the pupil learns about hierarchical classification. Fishes, amphibians, reptiles, birds, and mammals can be combined to form a superclass of "animals with backbones." Furthermore, certain things are logically true of the superclass and the subclasses (e.g., each member of the subclass must contain those characteristics that distinguish the superclass plus some others; a subclass is always smaller in number than the superclass.

Logical thinking is also demanded of the child in questions in the text or in the teaching suggestions.

Note the logical processes involved as a third grader attempts to answer the teacher's, "Can you give me an example of an animal that lives on the desert and explain how the animal can live in such an environment?" The pupil has read the unit "How Animals Live," Book 3, Unit 4, from which he learned about many animals adapted to many different environments. To answer the question, he must first combine elements that make up a set of desert conditions: little water, extremes of temperature, scarcity of food, little ground cover. He remembers the kangaroo rat as living on the desert, and combines elements that make up a set of rat characteristics: eats seeds and gets water from seeds, has sharp claws and can dig burrows, stays underground during heat of day and so needs less water, has eyes with many rods and so can hunt in the cool of the night. Then the pupil must set up a correspondence between elements in the desert-conditions set and elements in the rat set. If for the elements in the first set there are corresponding members in the other set, establishing an identity, then he knows the animal is adapted to desert living.

Logical operations continue to be emphasized in Grades 5 and 6, but in increasingly more complex situations. We can find many examples of operations particularly in the physical science content in Books 5 and 6. The development of the speed-time-distance relationship in Book 6 is a case in point. Note that the pupil must now see one variable as a function of two others and work out relationships among the three by using not one but several logical operations (reversibility, for example: if $s \times t = d$, then $s = d/t$; identity, as he puts in the correct numbers for the letter symbols).

Beginning in Book 5 and increasingly in Book 6, content encourages the pupil to do propositional



thinking. For example, in the introductory unit to Book 5, the reader is introduced to the specifics of scientific methods. He has, of course, been raising questions and doing "experiments" in the first three grades; he has even had practice in controlling certain factors while he experimented with another. In Book 2, for example, in the unit on heat, pupils experiment on the insulating qualities of different kinds of cloth. The size of the cloth and the temperature of the water to be protected are kept constant. But the question, "Does the color of clothes make a difference (in keeping us cool)?" is not stated as a hypothesis for testing. It implies a concrete operation, but it does not spell out the specifics for testing. It does, however, provide readiness for the fifth grader's encountering, in Unit 8, Book 5, the experiment, "How Do Dark and Light Colors Affect the Absorption of Heat Energy?"

There is one last point to consider in using the content of *Science for Tomorrow's World* to improve thinking processes. As Piaget has shown, the child deals less with the concrete and more with the abstract and the formal as thinking processes mature. We recognize this developmental change and have taken it into account in our planning to facilitate the appearance of abstract thinking, but we do not emphasize the formal expression of generalizations prematurely. There are many opportunities in the primary grades for pupils to deal with functions in a concrete way. In Book 2, for example, page 138, the pupil carries out an activity in which he discovers that the loss of heat over time is a function of the insulating properties of the protective material. This discovery as stated, however, is beyond the comprehension of most second grade children. Instead, the child of 7 summarizes in a concrete fashion: "With a wrapping made of wool, water doesn't cool off as fast as with wrappings made of cotton or rayon." In keeping with developmental theory, we reserve the more formal and abstract expressions of generalizations for Book 5 and Book 6.

Implications of Cognitive Theory for Activities and Illustrations

Cognitive theory is useful not only in planning content and grade placement, but also in planning learning activities and experiments and in designing special illustrations for tests. The reader will recall that in Piaget's theory, the first stage is the sensorimotor, where the infant may be said to "think with his muscles." While language changes the mode of thinking, the need for a motor component as an underpinning for certain concepts does not disappear with the advent of speech. Bruner in particular has noted the importance of motor activity as a first step in concept building. In this series we have recognized the importance of sensorimotor experience in planning learning activities. No verbal description of how gears work can substitute for the actual manipulation of gears (See Book 2, p. 52). No verbal description can convince the child that the image formed in the retina of what he is seeing is an upside-down image, but let him try building a pinhole camera (Book 6, Unit 6), and he has built into his sensorimotor system a basic understanding of the concept.

Activities with a motor component are not new to science, but what is new is that we now have a rationale for which concepts need this kind of sensorimotor underpinning. Concepts from the physical sciences, where two different displacements occur at the same time, need a motor component. The activities in Books 2, 3, and 6 in the units dealing with concepts of forces and motion contain many examples of such displacements. Sensorimotor activities are often needed, also, to correct misconceptions children have built up. Cognitive theorists have provided us with information about which concepts children are likely to be confused about. In the process of living and adjusting to his environment, the child has been dealing with such phenomena as time, matter, space, light, heat, motion, and electricity, and has more likely than

not built up misconceptions around them. Most children, for example, think that a steady push on an object results in a steady speed. The sensorimotor experience of feeling acceleration in the wagon one pushes with a steady push (Book 2, p. 39) *really* convinces the child in a way that telling him does not. Similarly, most children find it hard to believe that a ball flicked off from a table top and one dropped over the side at the same time will both reach the ground at the same time (Book 6, Unit 3). Understanding that a missile has both a horizontal and a vertical component of motion begins with a sensorimotor experience. (Book 5, Unit 8). And the future student of high school chemistry who has spent time in elementary school constructing models of atoms (Book 5, Unit 6) will find that the theory of chemical bonding comes naturally to him; he can imagine a model of the oxygen atom from his experiences.

Note that each of the activities mentioned helps to correct a misconception or to build a mental image of how something in the physical world *works*. Too much science-teaching time has been wasted in the past on activities with no foundation in an important science concept. Simply building a space station with model rockets in the classroom cannot be justified in terms of its cognitive value. While the activity has motor components, it probably generates more misconceptions than it clears up and contributes nothing to an understanding of the physics of space travel.

Following the sensorimotor experience (or assuming one in some cases), Bruner describes an *iconic* step in concept-building. After "meaning in the muscles," the child must build a mental image of what it is he is acquiring knowledge about. In this series we have aided the development of this step in the type of illustration used in special cases. The first grade pupil is introduced to the concept of a system in equilibrium through a sensorimotor experience with the seesaw. Then *diagrams* of the system are presented, with distance and weight clearly indicated as the variables. The diagram serves the function of giving the child a mental image of the essentials in the system. It is a pared-down version of the illustration showing actual children seesawing. In Book 2, force diagrams are used, again after a sensorimotor experience, to show both size and direction of the force in question. In Book 6, physical experience involved in understanding time-distance relationships is provided in graph making, the end-product of which then serves the image-building function. In Book 6, Unit 1, also, the learner becomes acquainted with vectors and builds a mental image of velocity with vectors.

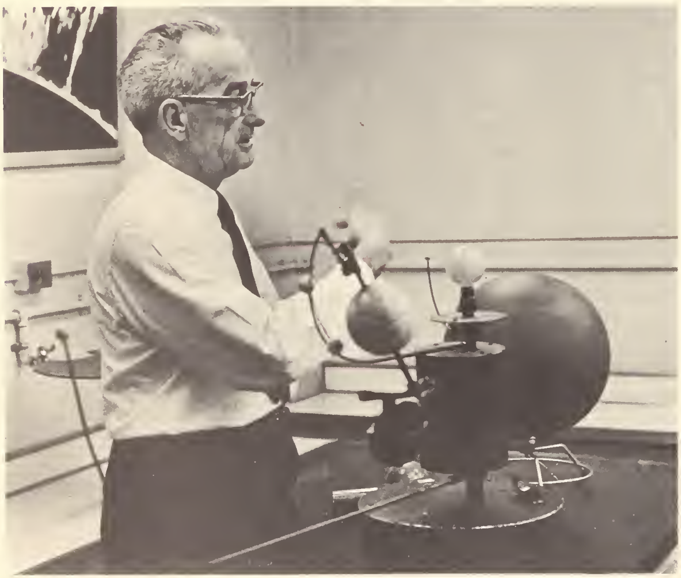
With the proper sensorimotor and mental-image underpinning, the learner can then go on to deal with a concept symbolically—that is, with language. Like adults, the pupil who has difficulty in understanding the sentence, "The intensity of light varies inversely with the square of the distance from the source," falls back on sensorimotor memories. If he has actually worked out activities involving the inverse-square law, then he has some "feel" for what the term means. If, in addition, he can also bring to mind a mental image of a diagram of the inverse-square law applied to light, then the sentence takes on additional meaning.

Motor activities, mental images, language—all three steps are not necessary for all concepts. For some concepts, pupils bring with them to school a strong sensorimotor, mental-image foundation, and are ready for the symbolic step. But for other concepts, where the foundation has been missing or faulty, one or both steps are essential. With many concepts, as Piaget points out, knowledge is deformed by a purely verbal approach. Teachers are being advised today, in science teaching, as in all teaching, to spend more time to teach what used to be covered in a few minutes with a few verbal statements. The advice is good—provided the teacher picks the right concepts to concentrate on, and provided the extra time is spent wisely on those steps that build readiness for the verbal stage.

PART III: SOME PROBLEMS OF METHOD IN TEACHING SCIENCE

PROBLEMS OF MOTIVATION

Psychologists are generally agreed that motivation is the first essential to learning. If pupils are to learn science, they must first *want* to learn; they must be motivated. However, there are a number of misconceptions with respect to how a state of motivation can be induced. Some teachers confuse motivation with external stimulation supplied to interest children in a lesson. Thus one teacher says, "But I have no trouble in getting my children motivated. I just produce a few pieces of equipment and tell the class we are going to have an experiment, and they are all interested."



Readers will agree with the teacher that children are immediately attentive when an experiment is proposed, but teachers will also recognize that interest in observing an experiment does not necessarily lead to motivation to learn important science concepts. The behavior of children who receive chemistry sets for a holiday present is a case in point. Many a child delights in mixing the chemicals and watching the resultant change in color or state of matter, but for too many it is the magical "result" that intrigues, rather than the chemistry of the change.

For the psychologist, however, motivation is intrinsic to the organism. It is no secret that even the very young infant learns spontaneously and enjoys the process. Furthermore, he is motivated to learn even when there is no adult present to supply initial stimulation. A ten-month-old baby who wants a toy that is out of reach on a cushion in his crib discovers that by pulling on the cushion he can bring the toy within grasp. He is learning that one can use tools (the cushion) to extend the arm to reach objects in space. The motivation for the learning came from within.

Teachers, too, can give many examples of intrinsic motivation. In Book 6, in the unit entitled "The Nature of Light," an activity is described involving use of a homemade ripple tank to study the behavior of light waves. Sixth grade children with access to this equipment have been observed before school and in free time, placing obstacles across the tank or inserting sharp-edged rulers below the surface of the water, to see what happens to the waves they create with a dowel stick. Fourth grade children studying electricity hurry to the science table when assignments are finished, to experiment by winding wire around a nail for so many turns to find out the effect upon the strength of an electromagnet. There appears to be a basic urge to explore, to find out how the environment

can be changed, and to learn what consequences flow from these changes. When this motivation to interact with the environment is present, the child carries on activities with considerable persistence, getting interesting feedback from his efforts and acquiring knowledge in the process. In the language of Piaget, the child assimilates and accommodates, restoring mental equilibrium when accommodation has been achieved.

It is not difficult to find examples of self-motivation in pupil behavior. The problem for the teacher, however, is to set the stage so as to produce this kind of behavior. More specifically, it is the problem of how to induce intrinsic motivation so that the pupil learns what the teacher wants him to learn.

Let us consider the case of a fourth grade teacher who is about to teach a unit on sound. Among the concepts that she wants pupils to acquire are: (1) In order for sound to be produced, something must vibrate; (2) For human beings to hear a sound, vibrations must occur between sixteen times and twenty thousand times a second; (3) The kind of sound one hears depends on the number of vibrations. We know that pupils will acquire these concepts through a self-regulatory process, but what can the teacher do, what stimulation can she furnish, to get the process started?

Theorists of learning have identified the elements that make a situation stimulating and that induce intrinsic motivation. One such element is that of novelty. A relatively less familiar situation is more stimulating than the familiar, and human beings (lower animals, too) clearly prefer the novel to the well known. The situation, however, must not be too novel, for too much uncertainty breeds fear and withdrawal.

Some theorists prefer to call the stimulating element "cognitive dissonance." By that they mean that there must be a discrepancy between information already stored in the brain and information coming in from an ongoing experience. When incongruity exists, there is a basic urge to resolve it so that mental equilibrium is restored. A pupil may presently believe that the way to make a stronger electromagnet is to make it bigger; bigness and strength are associated in his mind. Thus he would predict that a heavy spike will attract heavier objects than a slim nail. Faced with evidence that contradicts this belief, he then experiments with nails of various sizes and with various turns of the wire to find out what actually increases the strength of an electromagnet. He acts to get rid of the incongruity and to restore equilibrium.

The problem, then, for the teacher who would induce motivation in children is to provide encounters with objects or situations that will be incongruous with information children already have. To provide such encounters, the teacher must first know where children are in their thinking with respect to the concepts to be taught. If the teacher wants pupils to acquire the concepts we have listed for the unit on sound, then the teacher must first know what the pupils already believe about how sounds are produced and what the pupils believe about the reasons that sounds are different in pitch and intensity.

One way to find out what pupils already believe is to ask them. A teacher can start a lesson with questions based on the concepts to be taught. Thus, the teacher might begin with the question, "What makes a sound?" To such a question the teacher is likely to get an answer like, "There's a sound when we hit something." The teacher counters this response by asking, "Are all sounds made by hitting something? Who can give me an example of a sound that is made without something being hit?" Examples such as shuffling a shoe across the floor, rubbing the desk with the back of the fist, speaking, etc., are incongruous with the notion that something must be hit for sound to be produced, and pupils are motivated to find out what *is* the common element in all of the examples that produces sound. A discussion centered around questions designed to expose the incongruity between presently held beliefs and evidence to the contrary can induce motivation to resolve the discrepancy.

Even better than the purely verbal approach to motivation is one involving motor activity. From the motor activity, a pupil can take in information not only through the auditory sense, but through the visual and tactile senses as well. Instead of using discussion and relying upon words to elicit cognitive dissonance regarding how sound is produced, pupils can engage in such activities as vibrating a ruler over the edge of the desk, snapping a rubber band held between the teeth, or observing dry cereal moving up and down on a vibrating drum top. Such motor activities are better than the verbal because (1) they are more interesting; therefore, pupils will be more attentive; and (2) they permit more information to be assimilated (the actual information input is greater than when discussion alone is used). The advantage of the motor over the verbal is only true, however, if the motor activity can produce enough novel stimuli to be motivating. A motor activity from which the child can perceive only stimuli too elementary for his level of cognitive development is obviously a waste of time.

Throughout *The Macmillan Science Series,* many activities are introduced that are designed to induce pupil motivation. These activities take more class time than a verbal discussion, but teachers are urged to take the time for them. Only as the pupil becomes aware of the discrepancy between what he has believed and the actual evidence he is assimilating from an activity will he be motivated to acquire new knowledge. Assimilation is facilitated by activities that permit a multisensory approach rather than a purely auditory approach.

We can summarize the modern approach to motivation as follows:

1. The teacher must have clearly in mind the concepts the children are to acquire in connection with the study of a particular topic. These generalizations are listed for each unit in the Teachers' Guide.

2. The teacher uses discussion or, even better, a demonstration or individual pupil activity to stimulate pupil thinking about a particular concept.

3. The teacher asks questions or redirects pupils' observations in order to reveal any discrepancy between stored information and informational input.

4. The discrepancy is stated as a problem to be resolved in the course of the lesson.

PLANNING FOR INDIVIDUAL DIFFERENCES

As in teaching any other school subject, the classroom teacher must plan for individual differences in teaching science. And as is true in other school subjects, individual differences in reading ability create the biggest problem. A fourth grade class of 30 pupils may have a reading range that varies from second to sixth grade ability. How can the teacher accommodate such a range? Teaching pupils in separate groups as is commonly done in reading and arithmetic is not feasible; there is a limit to the number of separate lessons a single individual can teach in a day's time. Nor is grouping within the classroom desirable, except on a temporary basis, for subjects like science and social studies, if each grouping involves a separate body of subject matter. In these subjects there is a core of concepts that should be part of the curriculum for all pupils. All pupils in a particular grade ought to have the chance to acquire those concepts at the level of difficulty possible for them. Some fourth grade pupils may acquire simpler concepts about energy such as "Energy can be transformed from one form to another in order to get work done," while others may tackle more sophisticated concepts such as, "When energy is transformed, the total energy at the beginning and end of the transformation is the same." Managing such a range is quite possible for the teacher.

To provide for the slow readers, it is necessary to find books at their reading level treating the same unit that is being studied by the rest of the class. This is often possible to do in a subject like science, where many of the same topics are encountered in alternate years or every third year. Motion, for example, is studied in grades 2, 3, 5, and 6; weather is a topic in grades 1, 4, and 5; units on living things appear in grades 2, 3, 4, 5, and 6. Other examples of a spiral organization can be found by scanning the complete Table of Contents, which appears in Part IV. Many schools are operating on a flexible plan with regard to the use of texts, taking advantage of the spiral organization in order to meet individual differences. A sixth grade teacher, for example, who has pupils who are retarded in reading, borrows from the third or fourth grade for the particular unit being studied. She introduces the unit in exactly the same way to the entire class, but after pupils have completed their differentiated reading assignments, she introduces into the class discussion some questions aimed at the less sophisticated concepts covered in the easier book. This part of the discussion serves as a review for pupils who are more advanced in concept development. At the same time, the slow learners have the advantage of seeing the demonstrations and following the discussion of harder concepts, all of which serves as readiness for acquiring the concepts when they are encountered later on. As every teacher knows, it is often the *second* explanation that makes assimilation and accommodation possible.

But what does the teacher do in the case of units *not* covered in an easier book? One solution is to vary the reading assignment, requiring slow readers to read less material. Some teachers work with the slow readers as a group, having the material read silently in small sections and its meaning discussed at the end of each section. Under no condition should a pupil be given a book that is beyond his comprehension, unless special help is also provided. Nothing will stifle pupil interest in science more quickly than a teacher who requires the class to read books that are too difficult. As is true both in social studies and in science, the content lesson is also a reading lesson, and the same principles of reading that hold true when pupils are using readers are valid when pupils are reading science texts.

Of particular importance to slow readers are activities and experiments. Slow learners need even more in the way of sensorimotor experiences than do fast learners. The slow-learning third grade pupil can learn the concept of force only by actually setting objects in motion under varying conditions. There is a temptation because they read so slowly to have slow learners spend more time on reading and less on activities. Reading assignments, however, should be adjusted for these pupils so that they also have time to engage in experimentation.

In the past decade, much has been written about the gifted child and about the necessity of providing him with challenging situations. A great deal of effort has been expended in the direction of providing enrichment activities. Unfortunately, however, so-called enrichment activities too often involve only *busy work;* that is, the activity keeps the child *busy,* but at exactly the same cognitive level that he has covered so far. A bright child can be kept busy working on an animal chart on which he lists animals, names of the baby animals, and where the animals live, but at the same time the activity may offer nothing in the way of intellectual challenge. The gifted child needs enrichment in *depth,* rather than horizontal enrichment. He ought to have the chance to tackle intellectually challenging problems that will lead to the acquisition of concepts more sophisticated than those to which the rest of the class is exposed.

If we agree that the gifted child should have enrichment in depth, the next concern is how to provide it. Because the bright pupil is a good reader, some teachers are tempted to keep him busy with special

reports. He is the person assigned to look up topics in encyclopedias or other reference books; but such assignments are all too frequently carried out by copying lengthy excerpts from the source. Special reports need not, of course, be pedestrian or routine. A book such as *King Solomon's Ring,* by Konrad Lorenz, with its fascinating observations of animals, not only brings additional knowledge to the bright pupil in the fifth or sixth grade who reads it, but is likely also to inspire him to observe systematically his pet goldfish or dog, the birds in the backyard, the squirrels in the park, and other animals in his environment. But all science study cannot be carried on only through vicarious activities; directed observation and experimentation, to discover more advanced concepts or to apply acquired concepts to more difficult problems, should also be encouraged in the bright pupil.

Let us examine two different activities proposed in connection with the study of the unit entitled "How Animals Behave" (Book 6). One activity asks that the student find the answer to the question of whether differences between species or differences between breeds of the same species are greater. Pupils are instructed to carry on a series of observations on dogs and cats—recording the animals' approaches to food, their manner of eating, and their behavior after the food has been eaten. By selecting various breeds in each category, comparisons across breeds as well as across species can be made, and data can be gathered to answer the question. The activity serves as reinforcement for key ideas covered in the text; it is one that can be carried out even by slow learners who, hopefully, will become more aware of similarities and differences in animals. It is structured carefully so that directions can be followed easily. Note that alternative answers to the question under investigation are suggested: either the differences across species or the differences across breeds are greater; the problem for pupils is to find data to support one of the two possibilities—an easy task even for the slow learner.

Now let us examine a second activity suggested in connection with the unit "How Animals Behave." In this activity, the pupils are asked to select a category under which observations of animals might be collected—moving-about behaviors, courting, nesting, taking care of the young, and signaling. First the pupil must decide which category and what questions he will seek to answer about that category. Here, we will be concerned only with the "moving-about" behaviors of animals. A pupil might ask, "What is the effect of temperature change upon behavior? Do animals move faster or slower when the temperature rises?" To find the answer, the pupil must vary temperature conditions, choosing animals such as ladybugs, earthworms, or ants, which would be easy to collect and work with. He must plan and construct a temperature box, perhaps heating one end with an electric bulb while the other is left at room temperature or chilled by a tray of ice cubes. Next he must put the animals into the center of the box and observe their behavior. Then he must use his observations and those of his classmates *to discover key concepts* about moving-about behaviors, checking out the particular variable he has selected for testing and perhaps noting other variables worthy of trying out.

Note that this activity is not structured step by step for the pupil. He is not given a choice of hypotheses for testing; he must use his logical reasoning powers to figure out what is worthy of testing. Nor is he told what to do to test his hypotheses; the plan for experimentation will be a product of his own creativity.

Such an activity can provide the challenge to which bright pupils respond. When they first begin to do independent experimentation, they will need help. The teacher must teach them the process—how to select the variable for testing, how to set up adequate controls, and how to collect data.

To summarize, activities and experiments that place a high premium on logical reasoning and creativity must be provided for gifted pupils. Enough

help should be given so that they do not flounder, but they should be allowed independence in working out solutions to problems.

School Organization and Individual Differences

In recent years many innovations in the organization of the elementary school have been effected to take care of individual differences. Nongrading, team teaching, and dual-progress plans are three such innovations. No attempt will be made here to weigh the advantages and disadvantages of each plan; we will merely point out implications of each plan for the teaching of science.

In the nongraded school, grade labels are removed, and children are assigned to a teacher according to reading level. Thus one teacher of 8-year-old children might have an accelerated class capable of reading fourth grade books, while another, with a slow-moving section, might have pupils reading at the second grade level. Homogeneous grouping, whether on the basis of intelligence test scores or reading ability, has always had an appeal for teachers; teaching would be so much easier and more effective "if only individual differences could be taken care of by some kind of administrative device." Unfortunately (or fortunately, depending upon one's viewpoint), they cannot be. In an accelerated class of 8-year-olds, all the children may be able to read easy fourth grade books, but some can read fifth grade books and some do even better. The teacher must still cope with the problem of providing for those children who are capable of doing more advanced work.

A practical method of obtaining appropriate reading materials is to borrow books on the same subject from higher grades. Many teachers are reluctant to do this for fear that the teacher of the higher grades may say, "But what will they read when they are in *my* room?" The problem is one of coordination within a school so that plans are formulated to enable pupils to encounter challenging materials each year. In many schools, teachers pass along a list of the texts read in one year, so that the next year's teacher can plan realistically. In place of assigning texts according to average reading level, as is commonly done in nongraded schools, a teacher can select texts that will take individual pupils higher on the reading ladder. In place of a single text at one grade level, a teacher will have two or more levels to use with a class. Junior high school texts may be introduced into accelerated classes of twelve-year-olds if the need occurs.

Nongrading is a vertical form of organization of the elementary school; team teaching represents a horizontal form. In some schools, team teaching differs little from departmentalization, with different teachers who work as a team assuming the responsibility for teaching different subjects to the same children. As originally conceived, however, a team consisting of a master teacher and several assistants would be responsible for the instruction of about sixty children. The master teacher in a fourth grade might make a presentation to the whole group or conduct a demonstration, while assistants working with no more than fifteen children would supervise reading assignments and follow-up activities.

Team teaching offers certain advantages for science instruction, particularly in its provision for small-group work. The ratio of one assistant to fifteen pupils means many more opportunities for pupil participation in asking and answering questions and in engaging actively in experiments. Whether or not such opportunities are utilized depends, of course, on careful planning by the team. The practice of giving large group lectures or demonstrations, however, needs to be examined critically. It is a rare teacher, indeed, who can hold the attention of large groups of immature pupils for the length of a science lesson. Where team teaching is in vogue, it is better to confine the whole-group sessions to demonstrations requiring

much time to set up; these sessions should have a fast enough pace to ensure maximum pupil attention.

The dual-progress plan—another plan of organization—organizes the school both horizontally and vertically. For children above the third grade, the day is divided into two parts: graded and nongraded. Pupils spend the graded half of the day with a core teacher who teaches language arts and social studies. During the nongraded half of the day, subject-matter specialists take over, including one for science and arithmetic. For special subjects, children are grouped not according to age or grade, but according to aptitude, interest, and achievement. A fourth grade pupil, for example, if science is one of his strengths, might find himself with older children in the science class. For special subjects in which he is weak, he might find himself with younger children. Thus the plan provides for intraindividual variability—a distinct advantage in teaching a subject such as science where talent may become evident in the intermediate grades. An additional advantage is that the special teacher is usually better prepared in the subject matter and therefore presumably able to do a better job of building concepts.

TEACHING SCIENCE TO CULTURALLY DISADVANTAGED CHILDREN

There are teachers in both rural and urban areas of the United States whose classes consist almost entirely of children of the poor. These children present special learning problems, for their impoverished environment has not provided experiences that help mental structures to develop and intelligence to grow. Their homes lack the toys, books, pencils, paper, and mechanical equipment that offer opportunities for discovery. Their parents, themselves disadvantaged as children, lack the knowledge and skills, as well as the facility with language, to call children's attention to phenomena or to answer questions and raise problems; thus, it is difficult for them to furnish their children with science information and to make the children more curious about the world.

In his day-to-day living, the middle-class child has countless experiences that provide readiness for science. His picture books provide training in observation, sharpened by the mother's comments as she calls attention to details of size, color, shape, and cause-and-effect relationships. He takes a bath and observes floating objects in the tub. He goes for walks with parents who comment on shadows, budding trees, a squirrel's nest, how a woodpecker gets its food, and what the position of the sun in the sky tells us about the approach of suppertime. By the time he enters school, the middle-class child has developed mental structures upon which he can draw for solutions to new problems. The lower-class child, lacking the simple mental structures because of environmental limitations, often cannot grasp the more difficult problems with which he is confronted.

There are three ways in which the teacher can help to compensate for a child's impoverished background. First, the teacher must provide a rich language environment for the child. Language facilitates the development of logical thought. A child who doesn't know the names of domestic animals as common as "cow" is obviously going to have difficulty in learning the concept of "animal." A child who lacks the vocabulary to describe dimensions is not going to be able to deal adequately with the notion that as one dimension gets longer, another gets thinner.

The first two books in *The Macmillan Science Series* are illustrated profusely. The teacher can use the pictures to build vocabulary. The teacher can supply labels not only for objects but also for the properties of the objects—shape, color, texture, size, and weight. The teacher can introduce comparative terms such as "taller than," "heavier than," "darker than." The teacher can teach the terms to describe length, width, depth, weight, and other dimensions. The child who knows the terms is more aware of properties of

objects in his environment, and these can help him progress beyond the stage of sizing up an object in terms of whatever variable stands out perceptually.

Beyond the primary grades, the teacher must continue work on vocabulary development. Interestingly enough, it is not the technical vocabulary (e.g. "atom") that presents a problem (provided, of course, the teacher presents the technical terms with proper background); it is the vocabulary to carry on ordinary life activities, which should have been built during the early years, that is lacking. The child learns "pendulum," but he doesn't know the phrase "back and forth" to describe its movement. Getting children to talk about what is going on as they carry out experiments reveals these deficiencies. To counter this situation, the teacher can supply the terms, have the child use them, and review them in context from time to time.

The second recommendation for teaching science to culturally disadvantaged children is to provide more, not fewer, sensorimotor experiences than for middle-class children. The culturally deprived child cannot learn science solely by reading about it. He does not bring to the written word a reservoir of cognitive structures built up out of firsthand experiences. To understand the physical world, he must act upon it. There are 9-year-old culturally disadvantaged children who are *not* mentally retarded, but who do not know that if someone drops an object into a glass of water, the water level will rise. It is not enough for the child merely to read about the effect of one's actions; the child must experience it firsthand, assimilating information directly from the activity. Thus, in Book 2, if the disadvantaged child is to understand gears, he needs to use an eggbeater (a new experience for most children of that age) and observe how the gears are used to turn the beaters. Even more important, he needs to construct models of physical processes. As he makes and operates the endless belt described on pages 54 and 55, Book 2, he can see how, when one wheel is turned, the belt is made to move. He can see the force of the first moving wheel carried to the second. Such an experience builds the cognitive structures necessary to comprehend how a force is passed from one part of a machine to another part some distance away, and how twisting the belt into a figure eight makes the wheels turn in opposite directions and so changes the direction of the force.

Teachers will find additional activities included in the teaching suggestions at the sides of each page of text. Those involving actual motor activity are particularly appropriate in compensatory education.

The third suggestion for helping disadvantaged children is to build up their background of general information. Even at age 10, these children, in response to questioning, are likely to say that a duck is not a bird because ducks can't fly, and that birds and ducks can't be related because birds don't swim. Children can glean a great deal of general information from attractive picture books that are placed on the science table. One fourth grade child very nicely solved an animal-classification problem on the basis of information assimilated from picture books. As he put it, "I know ducks are birds because I could see in the pictures that there were some things the same, and I figured out that if it's got feathers and wings it's got to be a bird, and it doesn't count if it doesn't fly." In Piaget's language, equilibration occurred; the boy had given up an earlier, erroneous notion and accommodated the new information being assimilated.

Note that in all of the examples cited above there are opportunities for furthering logical development. The teacher can emphasize whole-part relations when discussing pictures with children. Relative terms such as "longer than" and "thinner than" aid children in understanding that a change in one dimension may be compensated for by a change in another, with resulting conservation. Testing of disadvantaged children at the University of Illinois reveals that they are lower on tests of logical development than middle-

class children. Compensatory education must include special attention to ensure the optimum development of logical processes in disadvantaged children.

FIELD STUDIES IN SCIENCE TEACHING

Science becomes meaningful for children only as it helps them interpret their environment. Classrooms, science books, audiovisual materials, and laboratory equipment are not the only means by which this purpose is to be achieved. At best they represent the beginning of the process. Ultimately, what is learned from a science book, a motion picture, or a laboratory demonstration must be applied or used in situations beyond the classroom if it is to have permanent educational value. Field studies are planned learning activities that take place outside the classroom.

Teachers often assume that once a science concept is dealt with in the classroom, pupils will use it on their own for out-of-classroom activities. It is possible that a few may do so, and rather extensively. Some may use the concept on a relatively limited scale. But many of the pupils may never relate the pertinent concepts to the things that are happening about them. For example, in a unit on conservation, pupils may read about ways in which runoff water erodes unprotected soil. They may view a film that shows the process taking place. They may even do a classroom experiment to measure the soil eroded from protected and unprotected surfaces by a measured quantity of runoff water. But what happens when the pupils *leave* the classroom? Do they recognize places where soil is being eroded? Do they suggest ways in which the erosion can be controlled? More important, do they attempt to do something about it? If the science of soil conservation is to become meaningful to pupils, learning about it must extend beyond the classroom into actual situations where the phenomena are taking place.

After considering the question of how science concepts dealing with soil conservation should be made more meaningful to pupils, a teacher might decide that three types of field studies would be appropriate.

One type has to do with locating places in the schoolyard or in nearby spots where soil is being eroded. Before the pupils started on their search, the teacher would alert them to the kinds of evidence that indicate that soil is being eroded. These include soil that has been washed onto sidewalks, roots of trees that have been exposed by the erosion of soil, small gulleys showing that erosion has started, and deltas of soil that have been deposited by water. After pupils had learned how to spot the evidence, they would proceed as a class or in small groups to locate places of erosion in the area. Following the group activity, pupils could be asked to look for other places near their homes and report their findings to the class.

A second type of field study might be to select one of the places where soil erosion is taking place and plan ways of stopping it. Ideally, this should be a place near the school where everyone can take part. Some pupils might undertake individual control projects in their own communities.

A third type of field study might be to visit a place where a planned procedure is being used on a large scale to control soil erosion. This might be a farm, a public park, a housing development, or new highway construction. The persons who are responsible for the plan would answer pupils' questions.

Based upon the above descriptions of three types of field studies having to do with soil erosion, it is reasonable to expect the following educational purposes to be accomplished by such activities:

1. Reinforcement of science concepts taught in the classroom by observing the concepts in action.

2. Development of the habit of viewing the environment in the light of concepts introduced in the classroom.

3. Recognition of situations that represent problems in need of solution.

4. Personal involvement in solving such problems and the development of the required skills.

5. Acquaintance with efforts to deal with such problems.

6. Acquaintance with agencies and people who assume responsibility for the problems in question.

There are a number of matters that must be considered when using field studies in teaching elementary school science.

Background Preparation

Generally, it is desirable to develop the pertinent conceptual background before undertaking a field study. In the above examples, reading about soil erosion and its causes (Book 3, "Our Planet Earth"; Book 6, "Life on the Earth"), viewing a film that shows how the process takes place, performing experiments to determine the effectiveness of plant cover in reducing erosion, and discussing the facts involved would help to build the essential conceptual background for the three field studies. This would give children the "eyes" with which to observe and interpret their observations.

Comprehensiveness of the Field Study

The field study should not be so comprehensive that teachers and pupils "get lost" in carrying it out. In the above examples, there were three distinct, manageable phases involved. Each phase had a specific purpose to accomplish. The first phase had to do with locating places where soil erosion was taking place. The second was the selection of one of these for further study. The third was finding out how other people solve the problem on a larger scale.

Personal Commitment

Wherever possible, the field study should provide for a personal commitment from each pupil. In these studies each pupil was encouraged to locate places where soil erosion was taking place in his neighborhood and to share his findings with the class. In addition to work on the class control project, individual pupils were encouraged to undertake small-scale control in their own neighborhoods.

Preplanning

Preplanning can pay high dividends in accomplishing the specific purposes of a field study. There are two aspects to preplanning: the teacher's preplanning by himself and the preplanning that the teacher does with his pupils. It is reasonable to assume that preplanning on the part of the teacher would lead to the decision to conduct the three field studies in the sequence described earlier. He would be responsible for planning and making decisions regarding the feasibility of various approaches to each study. He would also have the responsibility for making administrative arrangements. He would then involve his pupils in planning the details.

Prior to the first field study (that of locating places where erosion had taken place), the teacher and pupils would work together in deciding upon the kinds of evidence that they would look for. They would make plans for recording the evidence and indicating the places where the evidence was found. They would plan how to proceed from the classroom to the places they were going to visit. They would plan how the time allotted for the study would be used.

Field Studies as Investigations

Field studies should be carried out as investigations rather than as idle excursions away from school.

To be an investigation, a field study must have a clearly defined purpose. Although children will use many skills, such as those involved in communicating, observing, comparing, classifying, interpreting, and evaluating, the development of these should not become the primary purpose of a field study carried out as an investigation. Its purpose should be to obtain information and/or to solve a problem.

In the first field study on soil erosion, the purpose was to locate places where erosion was taking place. In the second, it was to suggest ways to control erosion in one of the locations. In the third, it was to find out how erosion is controlled on a large scale. The purpose of each investigation should be made clear to all who are involved in it. Each activity in the investigation should relate clearly to its purpose.

Where investigations involve the collection of specific data, plans should be made for recording them in an organized manner. The organization will be determined by the manner in which the data are to be used. For example, if the field study is to locate places where soil is being eroded by runoff water, a decision will have to be made regarding the area to be explored. Suppose it were limited to the school grounds or to a vacant lot near the school or to a three-square-block area adjacent to the school. Before the exploration was begun, a decision would have to be made regarding the method of recording the sites of erosion once they were found. In this case it would be reasonable to use a mapping method. A map would be drawn of the area. The map would be duplicated and each pupil given a copy. As erosion sites were found, they might be located on the map by placing an X at the appropriate spots. Some legend might even be used to indicate how severe the erosion was at the different sites. These data could then be referred to in selecting the one area that would become the test site for the control study.

Where the investigation has to do with solving the erosion problem in one of the places, other methods of recording data might be used. First, a record should be made of the nature and extent of erosion at the selected site. Next, the method by which the erosion is to be checked should be recorded. Finally, the report should be concluded with statements regarding the apparent success of the method used.

Where the investigation has to do with finding out what methods are used to control erosion on a large scale, the data would probably be recorded as answers to a list of questions prepared before the trip was taken to the site. Different pupils might be given the responsibility for obtaining answers to certain of the listed questions. After the answers were obtained, the study would be concluded by a written report that explained a method of controlling soil erosion on a large scale.

Each investigation should culminate in something that represents a record of what was accomplished as a result of the investigation. Investigations should run full cycle, from purpose back to purpose. The findings of the field study should be reported in ways that show how the purpose of the field study was accomplished.

The Size of the Group

Where it is impractical for the entire class to participate in a field study, a similar group of pupils or an individual pupil might conduct the study for the class. Suppose that the problem of transportation to the site where large-scale soil conservation was being practiced precluded the possibility of the entire class's making the trip. The teacher or one of the parents might take one or more pupils to the site. They could obtain answers to the questions that the class had prepared. Arrangements might even be made for them to take pictures to illustrate the various practices. These could be used in making a report to the whole class.

There are various ways in which teachers can learn about the types of field studies that might be

carried out by their pupils. In *Science for Tomorrow's World,* field studies are suggested at appropriate places in the pupil's text and in the Teachers' Annotated Edition:

BOOK 1
Visit a pet shop (p. 99).

BOOK 2
Compare the warm and cool ground outside your school or house (p. 111).

BOOK 3
Visit a planetarium (p. 35).
Plan a trip to a museum (p. 89).
Visit a food market or a farm (p. 219).

BOOK 4
Visit a public library (p. 131).
Visit a fire station (p. 309).
Visit a water purification plant (p. 314).

BOOK 5
Visit a botanical garden (p. 75).
Visit a drug company (p. 163).
Visit a textile factory (p. 208).
Visit a weather station (p. 261).

BOOK 6
Visit an electric utility company (p. 140).
Visit an astronomical observatory (p. 190).
Visit a biome (p. 296).
Visit a zoo (p. 341).

The soil erosion field studies described earlier come from this source. Generally, schools which have detailed courses of study include field studies among the suggested learning activities. *Science and Children,* published by the National Science Teachers Association, 1201 Sixteenth Street, N.W., Washington, D.C., is designed primarily for elementary school teachers. Each issue contains articles that include out-of-classroom activities in elementary science.

Some school systems supply teachers with guides to sites in the community where field studies may be conducted. These guides include such information as:

1. Name of site.
2. Location and directions for reaching it.
3. Age level for which its use is best suited.
4. Science topics to which the use of the site is related.
5. Data which might be obtained at the site.
6. Specimens or materials that could be collected.
7. Times most suitable for visiting.
8. Person with whom arrangements should be made.
9. Special regulations.
10. Safety factors to consider.
11. Evaluation statements made by those who have previously visited the site.

Sometimes good ideas for field studies can be obtained by talking over the problem with other teachers, especially secondary school science teachers. Finally, elementary school teachers should not underrate their own creative imagination in discovering field studies that will add a new dimension to their science teaching.

Evaluating Field Studies

After the field study is completed, it should be evaluated by teacher and pupils. One of the first questions to ask in evaluating a field study is, "Did it accomplish its purpose?" Where it failed, the next pertinent question is, "Why?" The answers to this latter question then become clues to the safeguards that should be exercised in the next field study.

Suppose, on their first soil erosion field study, children failed to find the evidences of soil erosion that had been anticipated by the teacher. This might indicate that the teacher had not done a careful job in selecting the area to be studied. It might mean that the children had not been properly briefed regarding the kinds of evidence for which to look. It might also mean that, for one reason or another, pupils had not observed carefully enough.

Suppose, on their second field study, the plan developed by the pupils did not control the erosion. This might be accounted for by the fact that they had not considered all causative factors and thus had not provided controls for some of them. It might also be that the plan was a good one, but they failed to carry out some phase of it.

Both teachers and pupils experience great disappointment when projects such as field studies do not turn out as expected. Both are tempted to forget the whole thing and to go on to something else. But there is always a reason for things not turning out as expected. To find the reasons and to carry out another study is an equally important educational experience. From it, pupils learn that one must have as many pertinent facts as possible before making his plan, and furthermore that his plan should take all pertinent facts into consideration. Finally, the pupil learns that the study must be carried out in terms of each detail of the plan.

Local Conditions

The use of field studies has to be adapted to local conditions. One local condition has to do with the availability of sites. The soil erosion field studies described earlier are those that could be carried out in most school situations. Even for schools located in cities where there are asphalt-covered playgrounds, the teacher and class should not have to go far from school to find a vacant lot or a small park area where soil is exposed. And wherever soil is exposed, there will be erosion. Somewhere, in practically every community, new buildings or houses are being constructed. Highway construction is taking place across the country. In these places, soil is being exposed to erosion.

Records of Field Studies

A file should be maintained of all completed field studies. The file, prepared by the teacher, might consist of one-page summaries of each field study, supplemented by a copy of one of the better reports written by the pupils. The teacher's summary should include the following information:

1. Purpose of the field study.
2. The science unit to which it is related.
3. The site and person with whom arrangements were made.
4. The number of pupils involved.
5. Persons who assisted with the study.
6. The date the study was begun and the date it was completed.
7. Problems encountered, along with notes as to how each problem was handled.
8. What pupils learned from the study.
9. Points to keep in mind in planning another, similar study.

Records such as these will be helpful not only in future planning of field studies, but also in sharing ideas about field studies with other teachers. The sharing might be in your own school or with many elementary school teachers through an article written for a journal such as *Science and Children*.

USING THE COMMUNITY

There are a number of good reasons why teachers should make maximum use of their communities in teaching science. The ways in which science relates to the lives of people can be effectively demonstrated by activities taking place in the community. In many communities there are people who are uniquely qualified to serve as authoritative sources of scientific information pertaining to many of the topics studied in class. Local institutions such as libraries, museums, planetariums, parks, zoos, and aquariums have been established as sources of information not usually available elsewhere in the community. Finally, through proper use of community resources, the people involved become better acquainted with the educational program of the school and the ways in which teachers are attempting to implement it. This is particularly important in elementary science, because science was not taught in the elementary school when many of the community's adults were pupils themselves.

Environmental Resources

Science teaching should begin with the ongoing experiences of children. It should move to other experiences from which children can gain more sophisticated insights or concepts. Finally, the new concepts should be used to reinterpret aspects of the immediate environment. Science then becomes a way of making the environment more meaningful.

The child's immediate environment is the community in which he lives. It is both a natural environment and a man-made environment. His natural environment includes the sky above him, the nearby woods and fields, streams and ponds, rain, wind, sunlight, clouds, snow, rocks and soil, plants and animals, and other people. His man-made environment includes school buildings and houses; bicycles, automobiles, trucks, tractors, and airplanes; highways, railroads, and streets; telephones, radios, and television; rockets and spacecraft; filling stations and airports; stoves and refrigerators; baseballs and bats; factories and stores; and even merry-go-rounds and Ferris wheels. Such an analysis as the above could be extended almost indefinitely. What is indicated is that the community represents a laboratory with almost unlimited resources for teaching science. In fact, the environmental resources in any community are so extensive that teachers may find it difficult to know where to begin.

Application of Concepts

You could begin by writing the title of each unit in your science text on a separate sheet of paper. Under each title, list the topics that are dealt with in that unit. Next to each topic, list activities in your community that might be used in helping to teach the concepts with which the topic deals. Here is an example of how this might be done for some of the topics in a unit on forces (Book 4, Unit 2):

UNIT: FORCES

Topics	*Community Activities and Objects to Which Concepts Apply:*
Making things move	Men loading a truck by hand; Men shoveling gravel; Hoist used by a construction gang working on a building.

Forces of different sizes	Bulldozer digging a basement for new apartment houses; Car lift at a local filling station; Automatic door-opener at a supermarket.
Measuring forces	Scales used in weighing baggage at an airline terminal; Scales for weighing trucks at inspection stations on highways; Scales for weighing children in the nurse's office; The recorded weight tests of fishing lines sold in a sporting goods store; Testing air pressure in tires at a filling station; Posted load limits on bridges; Posted load limits on elevators; Anemometer at a weather station.
Keeping things from moving	Brakes on automobiles; Prop reversal for slowing down airplanes; Retaining walls on the side of a steep hill; Plant cover to prevent soil erosion.
Balancing forces	Sanding icy streets; Supports on a stepladder; Timber braces in a mine; Supporting trees to protect from high winds; Bicycle stands; Door stops; Umbrella stops; Scaffolding to support workmen.
Forces have direction	Weather vane to indicate direction of winds; Hitting a baseball, a tennis ball, or a golf ball; throwing a baseball or a bowling ball; shooting baskets.

Going faster	Roller coaster; Streamlined cars; Skiing on steep slopes.
Changing directions	Steering wheels on automobiles; Rudders on airplanes; Handlebars on bicycles.

These are only a few local examples of how certain science concepts are applied. As you search for others, many more may be found. Once the searching process is started, pupils should be encouraged to take part. As pupils find additional examples, the meaning of the concept will become more firmly established in their minds.

The Community as a Source of Problems

The community not only provides many examples of how science concepts are being applied, but it is often a source of problems that require science for their solution. Here is an example of how one class became involved in an interesting local problem. At about the time the class had completed their study of a unit on conservation, an editorial dealing with the disposition of unsightly junked car bodies appeared in the local paper. The editorial proposed that the bodies be dumped into one of the Great Lakes—Lake Ontario. According to the editorial, this would remove an eyesore from the landscape and at the same time provide cover at the bottom of the lake for fish. In fact it was reported that local fishermen were in favor of the proposal.

Since pupils in this science class had learned about the importance of conserving metals, such as those used in making car bodies, they felt that the plan would be a waste of mineral resources. They believed it would be much better to reclaim the metal, and so they decided to write to the editor of the paper about their opinions. But their teacher encouraged them to check all of the facts involved in the situation before they wrote the letter.

A clipping of the editorial, along with an explanation of what the science class proposed to do, was sent to the United States Department of the Interior for evaluation. An assistant secretary of the Department replied with a two-page letter. Two paragraphs from his letter are quoted below:

> *With respect to the disposal of automobile bodies, it should be recognized first of all that the major part by weight of a junked car—the chassis—is very largely reclaimed, either for used parts or for steel furnace feed, before the unsightly body shell arrives in a so-called automobile graveyard. These shells have little or no reclamation value for several reasons. First, enormously expensive machinery must be maintained at the waste dealer's yard in order to compact the bulky shell into a form that can be charged into a furnace; second, a serious smog problem is involved in burning out organic material like upholstery before the compacting can take place; and third, the extensive electrical systems in modern automobiles introduce enough copper wiring in the shell to degrade the iron and steel reclaiming in smelting. The net result is the absence, in most instances, of a profit incentive for scrap dealers to reduce automobile bodies to a form saleable to steelmakers in competition with metal derived from cheap and plentiful iron ore.*

Disposal of automobile bodies in the Great Lakes raises other problems. The Department's Fish and Wildlife Service reports that auto bodies have been dumped offshore into salt water apparently without harmful effects, but without much benefit to the fish because the bodies tend to fill with silt and to lose form through rapid rusting. This Service notes, however, that disposal in the fresh water of the Great Lakes poses other objections, in particular, the absorption of the water's oxygen, during the rusting process, from waters already seriously deficient in this gas for the support of valuable aquatic life because of other wastes.

It is quite obvious that both the teacher and his pupils, through becoming involved in this community problem, had their concepts of conservation practices, as well as the science involved, extended considerably beyond the unit on conservation that they had studied. In addition, the pupils learned that one should get all the evidence before making a decision about a problem such as this one. At first the problem appeared to be a relatively simple one, with a clear-cut solution. However, it turned out to be much more complex. Finally, they learned how government agencies, such as the United States Department of the Interior, can be sources of information.

Resource People in the School and Community

In some schools, files are kept of the names and addresses of persons in the local community who may be used as resource persons for various purposes. These generally include teachers and other persons in the school. Where a school does not have such a file, it would be well to start one. A good place to begin would be with those who could be used as resource persons in the elementary science program.

In addition to their professional teaching competence, there often are teachers in school systems who have had other experiences that qualify them to serve as resource persons in elementary science. Included among these would be experiences in outdoor recreational activities such as hunting, fishing, bird watching, stargazing, boating, mountain climbing, and swimming; industries such as farming, manufacturing, lumbering, mining, construction, and transportation; institutions such as hospitals; agencies such as the Forest Service, National Park Service, and Conservation Service; and hobbies such as photography, radio, aviation, and even rocketry. There are people, other than teachers, in the community who have had experiences such as those enumerated above and who may be more available during school time. To find all of them becomes quite a problem. In some schools the P.T.A. takes on the job of locating them. This is generally done by sending out a suitable questionnaire to the patrons of the school. Where such an organized search is not possible, teachers may have to rely upon their pupils and other persons in the school to help locate resource people in the community.

Usually there are a number of professional people in communities who, by virtue of their professions, potentially qualify as resource persons in science. These include scientists, engineers, doctors, and nurses. There are others whose business or work may qualify them as resource persons. These include airplane pilots, firemen, laboratory technicians, food processers, manufacturers, builders, and automotive mechanics. A good way to locate others in this latter category is to examine the classified telephone directory of your community.

Museums as a Community Resource

If your school is located in a community that has a museum, you will surely want to use it as a

resource in your science teaching. Your school may have an inventory of the museum facilities available for school use. If it does, you should examine it to determine which ones would be suitable in your science course. If it doesn't, you can write to the curator of the museum for such information. Here is a partial list of exhibits listed in the general guide to one rather large museum:

Minerals and gems
Fossil fish
Dinosaurs
Ice age mammals
Insects and spiders
Fishes
Amphibians and reptiles
Birds
Mammals
Animal behavior
Man and his origin
The natural history of man
Ecology
North American forests

From a list such as this, you can select the two or three which you think might be worthwhile for your pupils to visit. Next, you should visit the museum to find out more about the exhibits you have selected. When you do this, plan to spend sufficient time to make a reasonably thorough study of each exhibit. Take notes on points of particular interest.

There are two ways in which you can get your pupils to the museum. Probably the best way is to arrange to take them yourself. If you do, have several parents accompany you to assist in supervising the children. Another way is to encourage parents to take their own children. Whichever way is used, some time must be spent in preparing the children for what they are to observe and how they are to observe it. This is where you will make use of the notes taken during your earlier visit to the museum. From these notes, you can prepare a statement regarding the general nature of the exhibits to be visited and how they are related to concepts that pupils have been studying, or will be studying, in science. Specific suggestions of what to look for should be given. These might be formulated as questions to be answered as students observe the exhibit. If you use the question technique, avoid making a large number of detailed questions. Long lists of such questions often result in children's not seeing the forest for the trees. For each selected exhibit, try to decide on the two, three, or four most important ideas with which it deals. Then formulate questions that will highlight the ideas. Regardless of whether you take your pupils or their parents take them, their preparation for the trip will be much the same. It is doubtful that children can experience anything but confusion from an unselective, unplanned, and unstructured trip to a museum. After the museum trip, there should be a time at school for review and summary of what was learned.

Planetariums as a Community Resource

In planetariums, a projector is used to display the movement of heavenly bodies on a hemispherical, or bowl-shaped, ceiling. The projector can be set to show how the heavenly bodies appear to rise in the east, move across the sky, and set in the west. It can also be used to show how the stars appear to an observer on the earth at various locations from the equator to the poles. Methods of locating constellations and prominent stars within them can also be demonstrated.

If there is a planetarium in or near your community, encourage your pupils to attend one of the demonstrations. Obviously this should be done near the time that they are studying about stars and planets in their science class. Since the director changes the planetarium show from time to time, you should try to keep informed about the current shows.

Planetariums usually arrange special showings for school-age children. It might be possible for you to combine a planetarium trip with a museum trip on the same day. As was the case for museum trips, children should be prepared for their visits to the planetarium. Admission fees are usually charged. However, special rates are given for school groups.

Parks as a Community Resource

Parks serve a number of functions in many communities. They are places where people may go for rest and recreation in natural surroundings of trees, shrubs, grass, streams, and ponds. They are places where people may go to learn more about the living things contained within the park. Parks generally contain a greater variety of trees and shrubs than may be found in any other place in the community. They can thus be used by teachers and pupils to observe various types of plant life and to identify similarities and differences among them. Parks can be used in the spring, summer, fall, and winter to demonstrate how the vegetation changes with the change in seasons. Parks usually have ponds or lakes that serve as a refuge for water birds such as ducks and geese. Because they are protected, the birds have become less afraid of people and can be observed from close quarters. Pupils can observe the forms and shapes of their bodies, their eating habits, and the manner in which they walk, fly, and swim.

Zoos as a Community Resource

From the point of view of children, zoos are among the most popular institutions in communities where they are maintained. Children enjoy observing animals. Visits to the zoo can become significant educational experiences in science if they are properly planned. In planning a trip to the zoo, teachers need to know what animals are kept there, from where the animals were obtained, and how they are cared for. This information can best be obtained by teachers visiting the zoo and having the educational director give them a conducted tour. For a group of teachers, the director may even include a "behind the scenes" tour of the zoo. On such a tour, teachers will be shown how food for the animals is selected and prepared, how animals are treated for injuries and sickness, how cages are cleaned, and how animals requiring special kinds of environments are protected. With background such as this, teachers can plan the zoo trip with their pupils so that it becomes an integral part of their study of science.

Institutional Aquariums as a Community Resource

Institutional aquariums are more difficult to maintain than zoos and, therefore, are not as common. But where they are maintained, they should be used by teachers to reinforce and extend science concepts related to the variety of living things and how living things are adapted to the environmental conditions in which they are found. The recommended procedures for using a zoo also apply to using an institutional aquarium. Because of the cost of maintaining an aquarium, there is usually an admission fee. As is true for planetariums, special rates are usually given to school groups.

Libraries as a Community Resource

Although firsthand experiences in observing, demonstrating, and experimenting are of paramount importance in learning science concepts and learning the methods of science, we should not leave children with the misconception that these are the only ways of learning about science. Books and periodicals are the most commonly used sources for learning about science. This is as true for the scientist as it is for

the nonscientist. Scientists and science laboratories could not be maintained without good libraries.

It is, therefore, important that the practice of using the library be encouraged, rather than discouraged, while pupils study science in the elementary schools. As evidence of the scientist's point of view regarding the importance of using good science books, the American Association for the Advancement of Science and the National Science Foundation publish bibliographies of science books for children. These bibliographies can be obtained by writing to the American Association for the Advancement of Science, 1515 Massachusetts Avenue, N.W., Washington, D.C., 20005.

Librarians report that a very high proportion of the questions that children bring to them deal with science. To provide for this interest, most libraries maintain a good selection of children's books on science. These books can be used for several purposes. They make it possible for children who want to find out more about certain science topics to do so. They supply information on new developments in science. Some deal with selected science topics in greater depth than is possible in a science textbook. Others present interesting biographies of notable scientists.

One of the best ways of finding out how you can encourage your pupils to use library books in science is to visit the science section of the children's reading room in the library in your community. Acquaint yourself with the wide selection of titles. Take out several books and read them. Then tell your children about the books. If this is done periodically, you can be sure that more and more of the children will begin using the library.

USING AUDIOVISUAL MATERIALS IN SCIENCE TEACHING

A great variety of audiovisual materials is being used in the teaching of science. They range from simple line diagrams drawn on the chalkboard by teachers to elaborate motion pictures that cost thousands of dollars to produce. All are designed to enhance teaching and learning through the use of the visual and/or auditory senses.

Audiovisual materials can be used to show objects, conditions, and events that are not immediately or directly available to pupils, thus extending the range of the pupils' classroom experiences. These may include such subjects as the research work of scientists in Antarctica, the earth as seen from a spacecraft, and conditions at the bottom of the ocean as photographed by a submarine camera.

Audiovisual materials can restructure the time and sequence of pupils' activities and experiences, thus making the activities and experiences more effective for educational purposes. Such materials include tape recordings of interviews, which become reliable records of questions asked by pupils and answers given by an authority on a topic being studied in science; pictures taken to produce reliable records of objects or processes observed during a field trip; pictures of the same child at different ages to show growth changes; slow-motion pictures of activities such as running, in which the sequence of body movements takes place so rapidly that it is difficult to observe the details; or time-lapse movies of events such as the opening of a flower bud, which takes place so slowly it is impossible to observe the details of the marvelous processes involved.

Audiovisual materials may be used to demonstrate procedures and to illustrate concepts in science. They can be used to show how to plan and conduct an experiment, to dissect an animal, to use a piece of apparatus, to prepare exhibits, to conduct a science fair, or to write a report. They can be used as an aid in explaining such concepts as the interdependence of living things, action-reaction, electric currents, work, chemical change, adaptations of living things, and practically any other concept studied in science. Audiovisual materials can be used to organize and

integrate concepts dealing with such topics as weather, nutrition, and spacecraft. They can be used as an aid in visualizing such concepts as the enormous solar system and the minute atom.

Types of Audiovisual Materials

There are two general types of audiovisual materials: those that require special equipment in order to use them and those for which no special equipment is needed. The following audiovisual materials require special equipment, such as cameras, projectors, recorders, microscopes, and phonograph machines:

- 16 mm. motion picture films
- 8 mm. motion picture films
- filmstrips
- 2″ x 2″ slides
- prepared microscope slides
- large transparencies for overhead projection
- recordings, both tape and disk

Among those materials that do not require special equipment are exhibits and models. The remainder of this section will deal with ways in which all of these materials can be used in teaching science.

Motion Pictures

The following list of selected titles, from the catalogue of one of the large producers of educational films, clearly indicates that science subjects are covered extensively by motion pictures and that films are available for every grade level:

FOR KINDERGARTEN AND GRADES 1–3

Animals and Their Foods
Electricity for Beginners
Energy Does Work
How Air Helps Us
How Animals Help Us
How Simple Machines Make Work Easier
Living and Non-Living Things
Rocks: Where They Come From
Sound for Beginners
Winter Comes to the Forest
Zoo Babies
The Big Sun and Our Earth
What Do We See in the Sky?

FOR GRADES 4–6

Air All About Us
Chemical Changes
Color and Light
Energy and Its Forms
Fossils: Clues to Prehistoric Times
Heat and Its Behavior
How Weather Is Forecast
Introducing Atoms and Nuclear Energy
Magnetism
Beyond Our Solar System
Adaptations of Plants and Animals
Fish and Their Characteristics
How Flowers Make Seeds

FOR GRADES 7–9

Airplanes: Principles of Flight
Conserving Our Forests
Electricity: How It Is Generated
Field Trip to a Fish Hatchery
Fire and Oxidation
Electrons and Electronics: An Introduction
Force and Motion
Latitude, Longitude, and Time Zones
Weather: Understanding Storms
Gravity
The Structure of the Earth
Behavior in Animals and Plants
Cell Biology: Life Functions

As is true in selecting any audiovisual material, films should be selected for use in science teaching only when they relate closely to the work at hand.

Furthermore, they should be suitable for the grade level at which they are to be used. Film catalogues carry descriptions of each listed film along with a statement regarding the grade level for which it is best suited. For example, here is a description of the one-reel, eleven-minute color film *Animals and Their Foods* given in the catalogue: "The animals in this film are divided into groups according to the foods they eat: (1) plant eaters; (2) meat eaters; and (3) those that eat both plants and meat. The illustrations explain the basic concept that different animals are suited to eating different kinds of food." Another example is the description for the film entitled *Electricity for Beginners:* "A flashlight that doesn't work leads Frank and Joan to a basic concept: Electricity flows only in a continuous pathway. Simple demonstrations in a hardware store show how electricity can produce heat, light, and magnetism, which in turn can produce motion in a small motor. The film also emphasizes the importance of safety with electricity."

Larger school systems usually maintain an audiovisual center for motion pictures such as those previously discussed. Where this is not the case, films have to be rented from an agency. Under such conditions, teachers often must plan for the use of specific films as much as a year in advance. But it is not always possible to anticipate the exact date upon which a specific topic will be used in a science class. Therefore, the dates for which films are ordered are usually tentative. But the films arrive on the dates ordered and can be kept for only a few days. It is not always possible to coordinate teaching with the prearranged film schedule. When this happens, teachers have to adapt their use of the film to fit the situation. When the film arrives ahead of the time that the topic for which it was selected is being studied, the teacher may find it necessary to use the film as a preview for what is to come in science. When it arrives after the topic has been studied, the teacher may find it advantageous to use the film as a review of the topic.

Much of the success experienced by teachers in using movie films is a direct result of the preparation they make for their use. They select only those films that are related to what they are teaching in science. They read carefully the teaching guide that accompanies the film to become better acquainted with its purpose and content. They preview the film to find out for themselves what it is all about. They prepare a suitable introduction to be used in presenting the film to their pupils. After the film is shown, it is discussed with pupils to make certain that its important points are reviewed and related to the work at hand.

Also available to teachers are 8 mm. cartridge-type film loops, known as single concept films. Such cartridge films require no threading, no rewinding, and only minimal handling. Each cartridge provides about three to five minutes of viewing time, pinpointing and highlighting a single concept. Thus, digestion, the structure of the atom, sound waves, and carbohydrates all might be subjects for the cartridge films. These films, although they do require special, moderately priced projection equipment, are an extremely valuable adjunct to the teaching of a lesson. They enable the teacher to point up a particular aspect of the lesson with ease and clarity.

Filmstrips

There are filmstrips for practically every topic studied in science. Filmstrips have some advantages over movie films. Since they are less expensive, individual schools can have selected collections of them readily available for use in the classroom. It is easy to operate a filmstrip projector. Pupils can participate by asking questions and giving explanations during the time it is being shown. It can easily be reversed to review frames whenever desirable.

Some filmstrips are accompanied by sound records. The sound accompaniment is usually commentary for

each of the frames and must be synchronized with the pictures by the operator of the projector. The accompanying sound commentary covers all important points with which each frame deals. Printed commentaries are also supplied with filmstrips so that the teacher may read as the filmstrip is being shown. The use of a printed commentary gives the teacher the advantage of being able to pace the showing of the filmstrip to accommodate the reactions and questions of the viewers. It is desirable for teachers to preview the filmstrips before classroom use. Furthermore, only those filmstrips that relate closely to the topics being studied should be selected for use.

2″ x 2″ Slides

These are transparencies whose dimensions are 2 inches by 2 inches. Generally they are color transparencies. Most of the advantages of filmstrips also hold for 2″ x 2″ slides. Also, while the pictures in a filmstrip are arranged in a definite sequence, it is possible to arrange the 2″ x 2″ slides into whatever sequence seems appropriate at the time. The 2″ x 2″ slides have another advantage in that teachers and pupils can take their own pictures with the proper camera and use them to make up their own classroom collection of slides. Here is a list of subjects, each of which could be made into a picture story using 2″ x 2″ slides:

Seasons in Our Town
Machines Make Work Easier
The Care of Animal Pets
Evidence That Air Is a Substance
Increasing and Decreasing Friction
Evidences of the Water Cycle
Rates at Which Different Seeds Grow
Forces
Units of Measurement

Using the Microscope

The compound microscope is the type most commonly used in classrooms. This microscope has an eyepiece lens and an objective lens, each one magnifying the image of the object to be viewed. Light strikes the mirror near the base of the microscope and then passes through an opening in the stage. The light continues through the objective lens, the tube, and the eyepiece until it reaches the observer's eye.

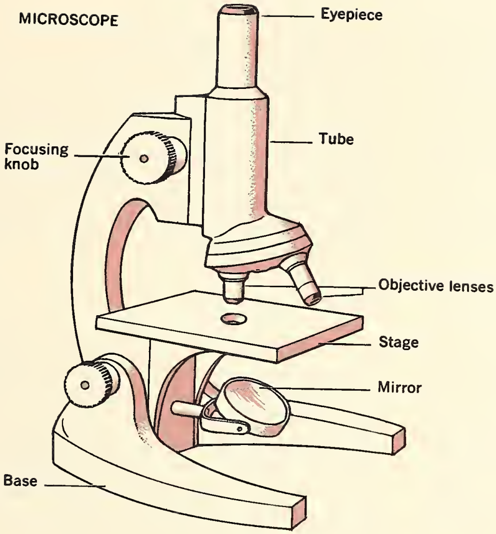
To magnify an object, it is necessary that only a *very thin* segment of the object be used. When magnifying onionskin, for example, use a razor blade to cut and peel off the thinnest possible layer. Place the layer on a glass slide and use a medicine dropper to add one drop of water to the layer. (Note: It is often possible to obtain a better image by using a drop of water-diluted iodine rather than plain water.) Next, place a cover glass over the glass slide.

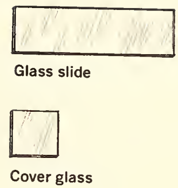
When focusing, place the microscope near a light source such as an open window or a lamp. Adjust the stage so that, when looking through the eyepiece, you see a bright circle of light. Next, with your eye away from the eyepiece, slowly turn the focusing knob, lowering the objective lens until it *almost touches* the cover glass. Look again through the eyepiece and slowly turn the focusing knob to *raise* the objective lens. When properly focused, the cells of the onionskin should appear as rectangular, or brick-like, shapes.

Prepared Microscope Slides

As early as the fourth grade, children should be introduced to the microscope. If possible, they should be shown how to prepare slides of living material such as yeast cells, cheek cells, microorganisms in pond water, and the cells of an elodea leaf.

There are limits to how far children can go in preparing their own slides of living material. At the





time that cells are being studied in science, it is desirable to have available a collection of prepared microscope slides of such subjects as paramecia, spirogyra, molds, bacteria, yeast, roots, stems, leaves, flower parts, human bone, human skin, human muscle, and human blood. These slides can be obtained from any biological supply house. Although they cost about $1.00 a slide, they are permanent slides, and with proper care they can be used for a long time.

A microprojector is an instrument that can be used to project the objects on microscope slides onto a sheet of paper. The projected image is enlarged, and it is thus possible for a number of children to see it at the same time. Even though a microprojector is used, children should also have an opportunity to view the slides through a microscope.

Large Transparencies for Overhead Projectors

The overhead projector is operated from the teacher's desk in the front of the classroom. As the teacher operates the projector, he faces the class and the picture is projected on a screen in back of him. Pictures are prepared on a transparent material and may be either black and white or colored. Their size is about 5 inches by 7 inches. As each picture is to be shown, it is placed upon the stage of the projector, where it is visible to the teacher during the time it is projected on the screen. This makes it possible for the teacher to face the class as he talks and to point out any part of the picture to which he wishes to call particular attention. Transparencies may be obtained from scientific supply houses on a number of

topics related to science. A catalogue of one supply house has listed the following series of transparencies for use in elementary science: Human Body Series, Animal Series, Astronomy Series, Atom Series, Geology Series, Meteorology Series, Electricity Series. The Astronomy Series consists of the Solar System, the Sun, Seasons; the Year, Month, and Day; Time Zones; Solar and Lunar Eclipses; Telescopes; and Satellites. This is an overlay series, which means that there is a set of four transparencies for each topic such as the Solar System. As each transparency in the series of four is laid upon the preceding one, it adds information to the ideas that are to be developed by the set.

"Do-it-yourself" kits are available for those who would like to make their own transparencies. The kits can be used to make diagrams, charts, and graphs. They can be produced in black and white or color. The audiovisual departments in some schools have persons skilled in making transparencies produce transparencies for teachers or teach them how to make their own.

Recordings

Both tape and disk recordings can be obtained on various subjects related to science. Some of the titles are listed below:

DISKS
American Bird Songs (an album of 6 records)
Adventures in Sound and Space
Science of Sound

TAPES
Electricity Goes to Work
Galileo Tests a Theory
Van Leeuwenhoek and the Little Animals
How Men Behave
Scientists at Work
Digging Up the Past
The Ocean and Weather
The Rocket Man
Satellite Story

The National Tape Recording Catalogue, published by the Department of Audiovisual Instruction of the National Education Society, lists more than one hundred titles dealing with topics in science. Many of them, such as the ones previously listed here, are appropriate for use in both elementary and junior high school science classes.

Exhibits

One of the most common uses of exhibits in science teaching is the science fair. Where science fairs are noncompetitive and voluntary, they may have very positive educational value. They encourage children to conduct projects of various kinds in coordination with their work in the science classroom. Children are also encouraged to organize the pertinent ideas into forms that are clearly visible. Imagination, creativity, and resourcefulness are applied in preparing science exhibits. In displaying their exhibits, children gain recognition for their efforts. Furthermore, children learn science from the exhibits prepared by other children. At their level, a science fair may serve much the same purpose that scientific meetings serve for the scientist.

In another section of this Teacher's Guide, the use of museum exhibits in teaching science has been discussed. Some museums prepare small exhibits of different kinds that are loaned to schools. These are prepared in glass-covered boxes for display. Generally, a guide book is sent with the exhibits to help the teacher get the most out of them.

Science museums have become quite popular in some of the larger cities. In these museums the exhibits have been prepared to teach people about scientific discoveries and technological inventions. Before a teacher makes a decision to take his class to a science

museum, he should visit the museum to determine which of the exhibits, if any, are related to topics being studied in his science class. If there are none, he probably should not make the effort to take his pupils.

Industrial firms include exhibits of various kinds among their educational materials. Generally, the exhibits are very attractive but deal rather exclusively with products and/or services in which the industry is primarily interested. Teachers should avoid cluttering up their classrooms with any such exhibits that are not closely related to topics being studied. Exhibits that are given to the school, or those that are pupil-made, often introduce storage problems that teachers find difficult to solve.

Posters of various kinds might be classified as exhibits. They can be used for many different purposes in science. Posters can be made to represent graphically such concepts as the water cycle, the oxygen cycle, interdependence of living things, the law of the lever, the conservation of energy, classification systems, the composition of the earth, electric circuits, and many other scientific concepts.

Models

There are many ways in which models can and should be used in teaching science. Often the use of a model is the only way in which the pupil can "get" the idea that the model represents. The globe of the earth, commonly found in classrooms, is a good example of such a model. It would be extremely difficult to think of the earth as a sphere without such a model. Models of the solar system serve a similar purpose. Models of the human skeleton, the brain, the heart, the eye, the ear, and other parts of the body can be used to help children obtain a better understanding of what the inside of the body is like. Models of atoms and molecules can be used to gain a better understanding of the building blocks of nature.

All the models mentioned above can be obtained from scientific supply houses. On the other hand, children can make many of them. If they do, they will probably come to understand the pertinent concepts better than when they use a commercially made model. In making a model of the solar system, children learn much more about comparative sizes and distances than when merely observing a manufactured one. Similarly, when they construct a model crystal, using toothpicks and wax balls, they come to understand the relative positions of atoms in crystals better than when they observe a prepared model. By using clay, pupils can make models of different kinds of cells, craters on the moon, fossils, the ocean floor, volcanoes, the brain, and molecules. Styrofoam balls of assorted sizes have been used in making models of planets and molecules. Cellophane bags can be used in making three-dimensional models of a typical cell. When given the opportunity, children delight in thinking up ways of making models of the different things they study in science. In the "thinking up" process, they are adding new dimensions to their understanding of the concepts.

CREATING INSTRUCTIONAL MATERIALS

In preparing a science program such as *The Macmillan Science Series,* it is impossible to anticipate every kind of learning situation that will confront the teacher in his day-to-day work. Schools vary from one community to the next. Classes within the school vary, as do the children within a particular class. For these reasons, teachers will find it advantageous from time to time to develop supplementary instructional materials adapted to the unique situations that they encounter in their teaching.

Because of the many ways in which learners may come to understand scientific concepts, the teaching of science provides unusual opportunities for teachers to create dynamic instructional materials. The re-

mainder of this section will include suggestions on how a teacher might begin.

Throughout *The Macmillan Science Series,* demonstrations are written into the text to introduce problems or to reinforce concepts. Additional material is suggested in the TAE. There are other ways, too, beyond those suggested in the TAE whereby concepts and their application can be demonstrated. Here are some questions to think about:

1. What are some ways, other than those given in the text, that can be used to demonstrate that air occupies space?

2. How many ways can you show that vibrating objects produce sound?

3. How many examples can you find of the fact that living things are interdependent?

4. In what situations have you witnessed the concept that once a body is set into motion it continues in a straight-line motion of unchanging velocity until acted upon by an unbalanced outside force?

5. In what other ways can you demonstrate diffusion as an example of the movement of molecules of one substance throughout another?

Questions such as these can be asked about every science concept that is demonstrated in your science text. They can serve as guides to "thinking up" or creating additional demonstrations. The more demonstrations or examples of a concept that can be shown to pupils, the better will be their understanding of it.

Creativity can really bloom when applied to the designing of experiments. Detailed descriptions are given for many experiments in the series. This is done to help pupils learn how the various factors in an experiment are handled. It may be that, for some pupils, more experiments of this type should be given, and it is here that the teacher could profitably spend some time in developing additional ones. In some instances it might be advantageous to modify one of the experiments in the text to include different materials and different experimental situations. For example, in an experiment where bread is used to determine the best conditions for mold growth, a variety of organic materials might be used in addition to bread. After observing the results of one such experiment, pupils frequently give the clue to new experiments by asking the question, "I wonder what would happen if this or that were done?"

The golden opportunity for developing new experiments often comes from something that happens during a science lesson. It may come from a searching question asked by one of the pupils. It may come from an unaccountable observation made by someone in the class. It may come when an experiment does not turn out as the class expected because the hypothesis being tested is not a tenable one. The following are examples of how this has happened in different classes.

In one class the teacher was performing a demonstration to show that soil contains air. As the teacher poured water into a large container of soil, bubbles formed at the surface of the soil. The teacher then asked the question, "What do the bubbles indicate?" As expected, one of the pupils replied. "It shows that there is air in the soil." The teacher followed with the question, "What did you observe that supported such a statement?" The pupil responded, "You could see bubbles which proved that air was coming out of the soil." The teacher then asked the class if they agreed. All but one boy did. He asked, "How do you know that the bubbles were formed by air rather than some other gas?" No one could answer the question, and the class now had a problem. How could you prove that the gas coming from the soil when you poured water into it was air? The teacher, working with a small group of pupils, devised a method for capturing the gas that was given

off when water was poured into the soil. They also devised ways of testing the gas to determine if, in fact, it was air.

In a third grade class the pupils had conducted an experiment to determine how temperature affects the growth of mold on bread. They had kept the moistened pieces of bread in small aluminum pans. As they had expected, considerable mold had developed on the bread that had been kept in a warm place. Little or no mold had developed on the pieces of bread that had been kept in the refrigerator. During the time each pupil was examining the bread mold in the pans, one of the pupils held the pan over his head. As he looked up at the bottom of the pan, he saw several tiny holes in it. He asked the teacher what caused them. The teacher commended him for discovering the holes and then asked the class how they could find out what caused the holes in the pan. This led to a series of very interesting activities, including experimentation and the use of several knowledgeable resource persons. Although the teacher and the children were not able to solve the problem through their own experiments, they learned a great deal about the limitations of their own knowledge and abilities and how to use resource people in solving complex problems. Investigation of the problem showed that carbon dioxide from the mold combined with salt from the bread to form sodium carbonate, which caused the holes to form in the aluminum.

In a fifth grade class the pupils had had a number of experiences in heating objects such as iron wire. They had found that heating the objects caused them to expand. The teacher had encouraged the pupils to give other examples from their own experience. Some mentioned that they had seen pictures of steel rails that had expanded on hot summer days and forced the railroad tracks out of shape. Others told of seeing the same thing happen on concrete highways. One girl in the class said she now knew why the drawers in her dresser became stuck in the summer. She explained that the heat expanded the wood so that the drawers became too tight to move in and out easily. Her explanation seemed reasonable to all members of the class. The teacher asked the class, however, if they were sure that wood expanded when heated. This was a good question, since they had done no experiments with wood. The class accepted the challenge to plan an experiment to test the hypothesis that "wood expands when heated."

In planning a method for testing the hypothesis, the children made many suggestions. With the help of the teacher, each suggestion was examined. Finally this plan was accepted: Three holes were bored into a piece of pine board. Then a length of wooden dowel was cut into three equal pieces. It was found convenient to use a one-inch pine board, to make the holes 3/8 inch in diameter, to get 3/8-inch dowels, and to make each piece four inches long. Each piece of dowel was numbered, and its hole was given the same number.

The first dowel was then put into an oven and heated at 200° F. for an hour. The second dowel was put into the freezing compartment of a refrigerator for an hour. The third dowel, the control, was left in the room.

At the end of the hour, each dowel was again fitted into its hole in the board. The heated dowel did not expand or stick as was expected, but fit more loosely than it had before it was heated. The cold dowel fit more tightly than before. The dowel that had been left in the room fit in the same way as it had before. The children were amazed. Some of them said, "Our experiment didn't work!" The teacher reassured them that the experiment had worked; it just didn't turn out as they had expected. Now the children really had a problem: If heat doesn't cause dresser drawers to stick in the summer, what does?

The teacher followed up by encouraging them to think of other possible reasons. After a while someone

suggested that it might be that high relative humidity on certain days in the summer caused the drawers to stick. How could this hypothesis be tested? Finally someone hit upon the idea of suspending one of the dowels in a covered jar that had water in the bottom of it. It was explained that the air above the water would soon become filled with water vapor, and the relative humidity would be very high. This seemed reasonable to the class, and so they hung one of the dowels above the water in the covered jar. They left it hanging this way until the next day. When they removed the dowel, they found that it had swollen so that they couldn't even force it into its hole.

As you can see, this experiment took several days to complete. Was it worth the time? This question can only be answered "Yes" if you believe that the creative thinking involved in planning an experiment such as this is important in the education of children.

Picture Stories and Other Supplementary Materials

The picture stories beginning with Book 3 have been used to reinforce concepts developed in the texts by showing how these concepts apply in human activities. There are many possibilities for applying the picture story technique to other concepts in local situations. For example, in Grade 1, where the concept of seasonal changes is introduced, a teacher might prepare a collection of snapshots of the class taken during the different seasons of the year. These could then be arranged in a picture story album or bulletin board display. Such a picture story would incorporate the local climatic conditions in ways that are not possible in a single standardized version of the concept of seasonal changes.

The possibilities for picture stories are practically unlimited. Whenever they are prepared, they should deal clearly with an application of one or more science concepts.

Teachers might also find it worthwhile to prepare supplementary materials for introducing certain units in the text. Bulletin board or large poster displays can be prepared, following the format used in the text. If this is done, the displays can be used to facilitate pupil discussion; they should be designed to help pupils understand better what the unit is about and to make more clear the purposes for studying it.

There may be local situations that relate in unique ways to certain of the units. Where this is so, supplementary materials can be prepared to show the relationship. For example, in communities near the ocean, the unit on oceanography (Book 5) would be introduced quite differently than it would be in communities far removed from the ocean. Because of the climatic differences among communities, units having to do with weather might be introduced in different ways. The unit on conservation (Book 6) would be introduced differently in urban communities than in rural communities. Thus, before undertaking any unit in science, the teacher should investigate possible ways of introducing it so that it relates most closely to the unique experiences of the pupils. When this is done, it will often lead to the development of unit introductory materials to supplement those in the text.

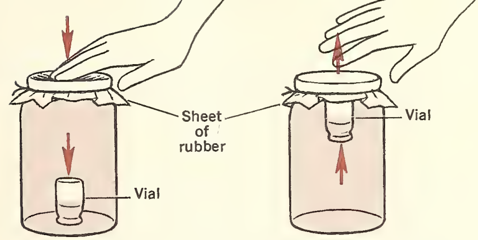
Reviews

One of the many strengths of *Science for Tomorrow's World* is the way in which units are reviewed. Review sections occur frequently and in a variety of interesting forms throughout each book. There are several phases involved in a review of concepts. One phase has to do with *recall* of the facts related to the concepts developed. A second has to do with *relating* the facts to the pertinent concepts. A third has to do with *applying the concept* or using it to explain something. A fourth has to do with using the concept to *predict* what will happen under certain conditions to which the concept applies. In other words, good re-

views provide for practice in identification, interpretation, application, and prediction. Since there are numerous commonly used ways of providing practice with each of these, the creating of new ways is an exciting challenge to any teacher.

Good reviews include the skills and attitudes involved in scientific inquiry. There are several ways of reviewing the skills involved in the planning of an experiment. One way is to present a problem which can be answered by experimentation and to then ask the pupils to plan the experiment. They might do this individually and then write up their plans. They might work in groups of four or five, and each group could then present its plan to the entire class. Or the entire class, with one of the pupils as the leader, might work up the plan. In the latter two instances, all pupils have the opportunity to take part in the evaluation of the planning. Reviews of this sort will be more effective if the teacher gives the students a novel problem—one that is not like any they have worked on before. Another way to provide for review of skills involved in experimentation is to keep a close record of an experiment, noting all pertinent details, including the results and the conclusions. Some of the common errors in experimentation should then be introduced into the record. Give the pupils the experiment as it is written, and ask each of them to evaluate it.

There are many ways in which skill in observation can be practiced through reviews. Demonstrations might be performed and pupils asked to record their observations. Where this is done, the demonstration must call for rather careful observation. One such activity might be the cartesian diver. One cartesian diver demonstration calls for a flat bottle filled with water and covered with rubber sheeting (see diagram). Suspended in the water is an inverted vial that is nearly filled with water. As the rubber sheeting is pressed, the vial goes down. As the pressure is released, the vial rises. The class is asked to tell why the vial went down and then up. The system under observation consists of bottle, water, vial, and hands. Those who have never seen the demonstration before must observe quite carefully to be able to tell that the vial goes down when the hands are pressing the rubber sheeting and that it comes up when the pressure is removed. There are many other demonstrations like this one that teachers could develop and use to give practice in observing.



Here is another example, which has to do with two scientific attitudes—objectivity in evaluating evidence, and reluctance to make a judgment until conclusive evidence has been accumulated. An investigation can be described in which data of both sound and dubious quality are reported. Based upon the evidence, certain conclusions are drawn. Some of the conclusions are consistent with the data, and some go beyond the data. After pupils have read the investigation, they are asked to evaluate the conclusions. What they react to in their evaluations should indicate whether they are weighing evidence and suspending judgment.

In this section we have seen that there are good reasons for teachers to create instructional materials. Through the process, teachers are providing for one of their basic needs, the need to be creative. Consequently, they gain greater satisfaction from their teaching. But more important are the values that come to the pupils who use the materials that the teachers prepare. The learning idiosyncrasies of pupils will be more nearly met, and their relative achievement in learning the concepts and using the methods of scientific inquiry will be improved.

OVERVIEWS OF UNITS IN BOOK 5

This section provides a brief overview of each unit in the book. At the end of the section you will find a listing of the table of contents of each book. This overall table of contents will give you an opportunity to visualize the total program of *Science for Tomorrow's World* and to see the interrelationships of subject matter in the conceptual organization of the series.

Unit One: The Scientist's Way—Testing Ideas

Each book in *Science for Tomorrow's World* contains a unit about one aspect of the methods of the scientist. This unit is concerned with the ways in which scientists test their ideas, in particular the formation of hypotheses. The youngster is led to find out what hypotheses are, how they are formed, and how they are tested. The unit goes on to discuss the use of valid ways of testing hypotheses. A discussion of probability theory concludes the unit and lays the groundwork for future units in the book.

Unit Two: Cells, Tissues, Organisms

One of the unifying theories of present-day biology is the *cell theory*. The currently accepted concepts in their simplest form can be stated as follows:

1. Cells are the units of *structure* of all living things.
2. Cells are the units of *function* of all living things.
3. Cells arise from living cells.

Cells performing similar functions are grouped into tissues; tissues organized to perform specific functions are known as organs. Organs form systems, which together make up an organized living system called an organism.

Unit Three: Growth and Development

This unit shows how from one cell an organism develops. The example of a chick's development is used to introduce the youngster to the branch of science known as embryology. By example the pupil learns the ways in which behavior changes as the environment changes. Plant development is also discussed, and the similarities to animal development are pointed out. The study of growth and development is in the forefront of scientific research and advances. The pathfinder in this unit is Dr. George Beadle, who was awarded the Nobel Prize for his work with *Neurospora*, a mold that has given us many clues about the developmental patterns of growth. The unit concludes with a discussion of human growth.

Unit Four: Systems of the Body

How the body maintains itself is the theme of this unit. The circulatory, digestive, respiratory, excretory, and skeletal systems are described. Much of the unit is concerned with the ways the body adjusts to change. This part of the unit deals with the nervous system, the network within the body that controls most of our behavior. Children will come to understand the functions of different parts of the nervous system, where these parts are located, and how to keep the nervous system in good order. Children will learn about the senses of smell, taste, and touch. They will discover that certain activities of the nervous system are automatic, while we have conscious control over others.

Unit Five: Conquering Disease

The story of man's battle against disease is set in its historic perspective in this unit, from the theories of Hippocrates and Galen to today's advances against viruses, bacteria, and other agents of disease. The unit deals with the kinds and causes of deficiency diseases, infectious diseases, and degenerative diseases. The body's defenses against disease are illustrated, and the ways in which we can control or cure diseases with disinfectants, heat, immunization, chemicals, surgery, and radiation are highlighted.

Unit Six: The World of Chemistry

Man's study of the atom is opening new horizons of knowledge. An understanding of chemistry is vital to an understanding of our world. This unit examines the three states of matter and their chemical and physical properties. The use of models in science is discussed when crystals are considered. The youngster is led to realize that knowledge about the crystal will lead to knowledge about how matter is put together in the universe. There are many investigations into elements, atoms, and molecules.

Unit Seven: Probing the Atmosphere

Knowing what the weather will be tomorrow is often vital and many times difficult for both layman and professional. What causes weather, what information the meteorologist collects, what new instruments today's meteorologist uses, and how the meteorologist forecasts the weather are of concern in this unit. The importance of keeping records and the ways in which this is done are emphasized. The youngster learns to read a weather map of the kind found in most of today's newspapers. In addition, in this unit the children are taken on a visit to a United States Weather Bureau office by way of an eight-page picture story. This effective teaching aid will provide many stimulating ways to motivate interest in this unit.

Unit Eight: Probing Outer Space

Again the historic approach is evident in this unit. It provides the proper frame of reference for the youngster to understand man's developments in the

exploration of outer space. Rockets and satellites—what they are, how they work, and the concepts *(Newton's Laws)* underlying how they work are discussed. The unit provides many opportunities for youngsters to do experiments. Weightlessness, G forces, food in space, cosmic rays and other dangers in space that men may encounter are dealt with. This information can easily be supplemented by newspaper reports and science magazines, as this unit deals in depth with today's and tomorrow's science.

Unit Nine: Probing the Oceans

Oceanography, the study of the oceans and seas, provides the subject matter for this unit. How the seas formed, how they have been explored, and what has been found are discussed. An eight-page picture story shows the methods used by oceanographers at work. The interdependence of plants and animals is a major concept in the section on the balance of life in the oceans.

SCIENCE FOR TOMORROW'S WORLD: BOOKS 1-6

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TESTS FOR SCIENCE FOR TOMORROW'S WORLD

On the following pages you will find tests for each unit in the book and for the two "Do You Remember?" sections. The Macmillan Company authorizes any teacher using *Science for Tomorrow's World,* Books 1–6, to reproduce *for use in his* or *her classroom only* the tests in this guide.

Unit 1: *The Scientist's Way—Testing Ideas*

Select the best answer to complete each statement.
Write the letter of the answer in the space at the right.

1. When a scientist has a problem to solve, he puts it in the form of — 1. b
   a. a theory
   b. a question
   c. a hypothesis

2. A possible answer that has not been tested or proved is called — 2. a
   a. a hypothesis
   b. an experiment
   c. a conclusion

3. "What causes wind?" is a — 3. b
   a. hypothesis
   b. question
   c. theory

4. Forming a hypothesis — 4. c
   a. is the same as solving a problem
   b. is easy even if you know nothing about the problem
   c. is guessing about the answer to a problem

5. To form a hypothesis you — 5. b
   a. use only your own research
   b. use information gathered from many sources
   c. must be a scientist

6. A Dutch scientist named Anton van Leeuwenhoek — 6. a
   a. invented the microscope
   b. formed an important theory about the universe
   c. helped man to use energy from atoms

7. Frequently a scientist will test a hypothesis by — 7. a
   a. experimenting
   b. asking his wife
   c. writing a letter to the library

8. If you toss a penny 100 times, it is — 8. __ __ c __ __
   a. impossible to get a head every time
   b. probable that you will get more heads than tails
   c. probable that heads will turn up 50 times

9. If you toss a coin 10 times and each time get a head, — 9. __ __ b __ __
   a. you will get a tail on the next toss
   b. you have one chance in two of getting a tail on the next toss
   c. you will get a head on the next toss

10. Michael Faraday performed experiments — 10. __ __ b __ __
   a. using the electric light bulb
   b. with magnets
   c. but he kept very sloppy records

11. A scientist's best tools are his — 11. __ __ c __ __
   a. expensive laboratory tools
   b. nose and ears
   c. trained mind and his natural curiosity

12. A scientist thinks and develops his ideas about problems — 12. __ __ b __ __
   a. only when working in his laboratory
   b. even when far away from his laboratory
   c. only during the hours of his work day

13. Before accepting a hypothesis as fact, a scientist tests it — 13. __ __ b __ __
   a. a few times
   b. many, many times
   c. once

14. Albert Einstein formed a very important theory about — 14. __ __ c __ __
   a. cell structure
   b. the microscope
   c. the universe

15. Atomic energy can be used — 15. __ __ a __ __
   a. for many peaceful purposes
   b. only in warfare
   c. only in warfare and as a source of energy in factories

16. If you toss two dimes in the air, the number of possible combinations is — 16. __ __ b __ __
   a. 3
   b. 4
   c. 5

17. Health insurance rates are — 17. c
    a. not affected by the probability theory
    b. sometimes affected by the probability theory
    c. very much affected by the probability theory
18. Marie and Pierre Curie found a new element called — 18. a
    a. polonium
    b. pitchblende
    c. uranium
19. Marie Curie discovered that — 19. b
    a. uranium ore gives off energy
    b. energy given off by uranium ore equals the uranium in the ore
    c. only one element had what she called radioactivity
20. Doctors can cure certain types of cancer by using — 20. c
    a. pitchblende
    b. uranium
    c. radium

Fill in the correct word or words for each sentence.

radium cells probability theory Nobel Prize theory

1. Scientists use **probability theory** to make predictions.
2. Schleiden and Schwann showed that all living things are made of **cells**.
3. A **theory** tries to show the connection among many facts.
4. Marie and Pierre Curie won the **Nobel Prize** for the discovery of radium.
5. Marie Curie died from a disease brought on by exposure to **radium**.

Unit 2: Cells, Tissues, Organisms

Select the best answer to complete each statement.
Write the letter of the answer in the space at the right.

1. The ameba is an animal made of — 1. a
    a. one simple cell
    b. many different cells
    c. several specialized cells

2. Robert Hooke made important observations about — 2. b
   a. the ameba
   b. a thin slice of cork
   c. the human brain

3. Your brain is made of — 3. b
   a. one big cell
   b. many specialized cells
   c. only cells that help you to read

4. Schwann and Schleiden advanced man's understanding of living things by — 4. c
   a. making DNA and RNA in the laboratory
   b. inventing the electron microscope
   c. explaining that all plants and animals are built of cells

5. Scientists believe that the nucleic acids DNA and RNA — 5. a
   a. are the key to the inheritance of certain characteristics
   b. are found only in a few animals
   c. can never be made in a laboratory

6. Unlike animal cells, plant cells have a covering called — 6. a
   a. a cell wall
   b. DNA
   c. a nucleus

7. A plant's cell wall is made of — 7. c
   a. cytoplasm
   b. muscle tissue
   c. cellulose

8. All living things begin life as — 8. b
   a. a tissue
   b. a single cell
   c. a double cell

9. The tissue that supports your body and holds your cells and other tissues together is called — 9. b
   a. covering tissue
   b. connective and supporting tissue
   c. muscle tissue

10. Messages are carried from one part of the body to another by — 10. a
    a. nerve tissue
    b. connective tissue
    c. covering tissue

11. Muscle tissue is made of 11. _ _ a _ _
    a. cells that are very much alike
    b. cells that look like blood tissue
    c. millions of cells, which are not all alike

12. The red blood cells of the human body 12. _ _ c _ _
    a. help to fight disease
    b. form a tissue that covers the inside surface of the body
    c. carry food and oxygen

13. An organ is 13. _ _ a _ _
    a. a group of tissues that work together
    b. another name for an organism
    c. an organized living system

14. The material around the nucleus of a cell is called 14. _ _ c _ _
    a. diatom
    b. helix
    c. cytoplasm

15. The tissue that enables your body to move is called 15. _ _ b _ _
    a. blood tissue
    b. muscle tissue
    c. covering tissue

16. The scientist who developed one of the first microscopes was 16. _ _ b _ _
    a. Arthur Kornberg
    b. Robert Hooke
    c. Theodor Schwann

17. Fats and proteins in living cells 17. _ _ b _ _
    a. dissolve in water
    b. mix with water
    c. will neither dissolve in water nor mix with it

18. An ameba is 18. _ _ c _ _
    a. a one-celled plant
    b. an organ
    c. an organism

19. A rabbit is an example of 19. _ _ b _ _
    a. a system
    b. an organism
    c. an organ

20. A cell membrane is made of
    a. material that is not living
    b. cellulose
    c. living material

20. __ __ c __ __

Fill in the correct word or name for each sentence.

tissues cells Henri Dutrochet Robert Hooke nucleus

1. Scientists now know that all plants and animals are made of **cells**.

2. **Henri Dutrochet** observed that growth results from an increase in the size of existing cells and from the addition of new, smaller cells which increase in size.

3. **Robert Hooke** described the holes in cork as "cells."

4. The **nucleus** directs the growth and reproduction of the cell.

5. Groups of similar cells are called **tissues**.

Unit 3: Growth and Development

Select the best answer to complete each statement.
Write the letter of the answer in the space at the right.

1. The egg cell of a hen is produced in the
    a. yolk
    b. ovary
    c. oviduct

1. __ __ b __ __

2. Sperm cells of a chicken are produced
    a. within the body of the male chicken
    b. by the yolk of the egg
    c. in the ovary of the hen

2. __ __ a __ __

3. The scientific study of the early development of living things is called
    a. entomology
    b. incubation
    c. embryology

3. __ __ c __ __

4. An incubation period is — 4. a
   a. the time required for a chick to develop from a single fertilized egg cell
   b. when the nucleus of the sperm cell joins with the nucleus of an egg cell
   c. when the egg cell passes through the oviduct

5. The outer skin, feathers, brain, and nervous system of the chicken — 5. c
   a. are formed from cells in the endoderm
   b. develop in the ovary
   c. are formed from cells in the ectoderm

6. The yolk — 6. b
   a. fertilizes the chick egg cell
   b. provides food for the chick embryo
   c. is a small spot, in the egg, that becomes the chick embryo

7. The embryos of many different animals develop — 7. a
   a. in a head-to-tail direction
   b. in a tail-to-head direction
   c. all over at the same rate

8. The chick embryo becomes fully formed and ready to hatch in — 8. b
   a. 9 months
   b. 21 days
   c. 6 days

9. The various stages in the development of a normal chick from a fertilized egg cell — 9. c
   a. change from year to year
   b. differ from one chick embryo to another
   c. are the same for all normal chickens

10. Between the two main halves of a lima bean seed is found — 10. b
   a. the seed coat
   b. the undeveloped plant
   c. stored food for the embryo

11. The ovules of a plant are formed in — 11. a
   a. the ovary
   b. the stamen
   c. pollen grains

12. Fertilization takes place in flowering plants — 12. __ __ a __ __
    a. when the nuclei of cells produced by pollen grains join with nuclei of ovule cells
    b. before the pollen grains land on the surface of the pistil
    c. after cell division has begun

13. The development of a plant's leaves, stem, and roots is called — 13. __ __ c __ __
    a. ovulation
    b. fertilization
    c. germination

14. Seeds — 14. __ __ a __ __
    a. take different periods of time to germinate
    b. all germinate in the same amount of time
    c. all germinate immediately after they are formed

15. The wormlike stage in the development of certain animals is called a — 15. __ __ a __ __
    a. larva
    b. pupa
    c. cocoon

16. In a cocoon — 16. __ __ b __ __
    a. the larva gets larger and larger
    b. a new moth develops from cells in the pupa
    c. the pupa changes many times to become a larva

17. The science of heredity is called — 17. __ __ a __ __
    a. genetics
    b. germination
    c. incubation

18. The case that a butterfly spins around itself in the pupa stage is called — 18. __ __ c __ __
    a. a cocoon
    b. a caterpillar
    c. a chrysalid

19. Dr. George Beadle and Dr. Edward Tatum studied — 19. __ __ a __ __
    a. red bread mold spores that had been exposed to X rays
    b. the development of chick embryos
    c. the stages of frog development

20. Your rate of growth — 20. __ __ b __ __
    a. is the same each year
    b. varies from year to year
    c. continues in spurts until you reach age 60

Fill in the correct word for each sentence.

hormones stamens tadpole pistil hormone

1. The tubelike part in the center of the flower is the **pistil**.
2. Pollen is a powdery material that may be found at the top of **stamens**
3. A **tadpole** is the fish like stage of a frog.
4. A **hormone** is a chemical that causes certain things to happen in the body.
5. The pituitary gland produces **hormones** that regulate bone growth rate.

Unit 4: Systems of the Body

Select the best answer to complete each statement.
Write the letter of the answer in the space at the right.

1. A bloodstream — 1. **b**
   a. carries only food and water
   b. carries everything the body cells need to maintain life
   c. is found in every living animal
2. The movement of molecules from a place where there are many to a place where there are fewer is called — 2. **c**
   a. circulation
   b. transportation
   c. diffusion
3. The life activities of a sponge depend on — 3. **c**
   a. a continuous flow of blood through its body
   b. an "open" blood system
   c. a continuous flow of water through its porous body
4. Your heart pumps blood — 4. **b**
   a. only to the lungs
   b. to the lungs and the rest of the body
   c. only to the brain
5. Veins — 5. **a**
   a. carry blood back to the heart from the capillaries
   b. carry blood away from the heart
   c. are not blood vessels

6. The beat in an artery is called a
   a. pump
   b. hormone
   c. pulse

6. __ __ c __ __

7. The stethoscope was invented by
   a. Théophile Laënnec
   b. Alexis St. Martin
   c. William Beaumont

7. __ __ a __ __

8. Undigested food leaves the body by way of the
   a. large intestine
   b. small intestine
   c. gullet

8. __ __ a __ __

9. Digestion is completed in the
   a. stomach
   b. salivary glands
   c. small intestine

9. __ __ c __ __

10. In an adult, the small intestine is about
    a. 20 feet long
    b. 4 feet long
    c. not as long as the large intestine

10. __ __ a __ __

11. Lungs fill with and then empty themselves of air because of
    a. the up and down movement of the diaphragm
    b. digestion in the gullet
    c. contraction of the windpipe

11. __ __ a __ __

12. The system in your body that enables you to get rid of wastes is the
    a. respiratory system
    b. excretory system
    c. digestive system

12. __ __ b __ __

13. Kidneys help to
    a. digest food
    b. carry oxygen to every cell
    c. filter your blood

13. __ __ c __ __

14. Where the end of one bone meets the end of one or more other bones, there is formed a
    a. joint
    b. contraction
    c. pivot

14. __ __ a __ __

15. Human beings adjust to change by
    a. changing their body temperature
    b. hibernating
    c. changing the world about them

15. __ __ **c** __ __

16. Unlike an electrical message, a nerve message
    a. travels along living cells
    b. travels back and forth along a wire
    c. travels only 30 feet a second

16. __ __ **a** __ __

17. Automatic body changes are caused by a hormone released from your
    a. cerebrum
    b. adrenal glands
    c. cerebellum

17. __ __ **b** __ __

18. Nerves carrying messages of touch, taste, and smell to your brain are
    a. motor nerves
    b. sensory nerves
    c. reflexes

18. __ __ **b** __ __

19. Your central nervous system is made up of
    a. the brain and respiratory system
    b. the brain and circulatory system
    c. the brain and spinal cord

19. __ __ **c** __ __

20. Pavlov's experiments with dogs
    a. showed that animals can be conditioned to react in certain ways
    b. showed that they were cold-blooded animals and adjusted to changes in their environment
    c. showed that dogs have no spinal cord

20. __ __ **a** __ __

Fill in the correct word or words for each sentence.

artery villi contract sweat glands circulates

1. Blood **circulates** through the body.
2. Doctors use the **artery** in your wrist to count your pulse.
3. Inside the **villi** are blood capillaries.
4. Muscles do work only when they **contract**.
5. **Sweat glands** remove water and salts from the blood and pour them through tiny openings in your skin.

Unit 5: Conquering Disease

Select the best answer to complete each statement.
Write the letter of the answer in the space at the right.

1. Diseases that occur when certain organs or systems of the body begin to wear out are called — 1. a
   a. degenerative diseases
   b. deficiency diseases
   c. infectious diseases

2. An example of an infectious disease is — 2. b
   a. rickets
   b. measles
   c. hardening of the arteries

3. Hippocrates believed that disease was caused by — 3. b
   a. evil spirits
   b. a lack of balance of the body humors
   c. a lack of balance of hot, dry, wet, and cold in the body

4. A process of killing bacteria in food so the food will not spoil is — 4. c
   a. culturing
   b. immunizing
   c. pasteurization

5. Pasteur's experiments with microorganisms led him — 5. b
   a. to be the first to discover "animalcules"
   b. to form the germ theory of disease
   c. to find the cause of anthrax

6. Robert Koch, a German physician, found that bacteria can grow coverings around themselves called — 6. b
   a. anthrax
   b. spores
   c. colonies

7. A virus is a very tiny bit of protein that — 7. c
   a. can be seen with an ordinary microscope
   b. can be cultured only on agar
   c. can be cultured only inside a living cell

8. Mumps is a disease caused by a 8. __ __ b __ __
   a. fungus
   b. virus
   c. bacterium

9. Chemicals such as alcohol, hydrogen peroxide, and iodine are known as 9. __ __ a __ __
   a. disinfectants
   b. antibodies
   c. vaccines

10. Tuberculosis and diptheria are diseases caused by 10. __ __ a __ __
    a. bacteria
    b. viruses
    c. fungi

11. Joseph Lister made air that was free of living organisms by 11. __ __ b __ __
    a. culturing the air
    b. sterilizing the air
    c. chilling the air

12. Soap is a good 12. __ __ b __ __
    a. antibiotic
    b. disinfectant
    c. vaccine

13. The moist lining inside your nose and throat that traps dust particles and microorganisms is called 13. __ __ a __ __
    a. the mucus membrane
    b. the white blood cell
    c. the humor

14. If you have had chicken pox, you are 14. __ __ c __ __
    a. immune to the disease only a short time
    b. never immune to the disease
    c. not likely to get this disease again

15. The Salk polio vaccination produces immunity to polio by the use of a 15. __ __ a __ __
    a. killed virus vaccine
    b. live virus vaccine
    c. live cowpox virus

16. Scientists have found that polio is caused by 16. __ __ b __ __
    a. an antibody
    b. a virus
    c. a bacteria

17. Dr. Paul Ehrlich discovered
    a. that sulfa drugs could be used effectively to kill microorganisms
    b. that chemicals could be used effectively to kill organisms within the body
    c. that certain mutant genes were resistant to sulfa drugs

17. __ __ **b** __ __

18. A germ-fighting substance produced by a living organism such as a bacterium, mold, or fungus is called
    a. an antibody
    b. an antibiotic
    c. an addict

18. __ __ **b** __ __

19. A person who is sensitive to a specific substance is said to be
    a. mutant
    b. resistant
    c. allergic

19. __ __ **c** __ __

20. The most common type of heart disease, which occurs mainly in older adults, is called
    a. cancer
    b. rheumatic fever
    c. arteriosclerosis

20. __ __ **c** __ __

Fill in the correct word or words for each sentence.

carbolic acid   microorganisms   mutant   vaccination   radiation

1. Organisms that are too small be seen by the unaided eye are called **micro-organisms** .

2. Joseph Lister found that the chemical **carbolic acid** could be used to kill bacteria in the air of the operating room.

3. **Radiation** is used to destroy or slow down the growth of cancer cells.

4. Dr. Edward Jenner's experiment of **vaccination** against smallpox provided a new way to conquer disease.

5. A **mutant** organism may not be affected by the chemicals that affect other bacteria of the same kind.

Do You Remember?—Units 1, 2, 3, 4, 5

Select the best answer to complete each statement.
Write the letter of the answer in the space at the right.

1. A possible answer to a problem is called a — 1. b
   a. conclusion
   b. hypothesis
   c. question
2. A hypothesis that correctly shows the connection among many facts is called a — 2. c
   a. probability
   b. convection
   c. theory
3. If you toss a penny 20 times and each time get a head, — 3. c
   a. it is probable that on the next toss you will get a tail
   b. it is probable that on the next toss you will get a head
   c. you have one chance out of two of getting a tail on the next toss
4. In 1903, Marie and Pierre Curie won the Nobel Prize for their discovery of — 4. b
   a. uranium
   b. radium
   c. pitchblende
5. A Dutch scientist named Anton van Leeuwenhoek — 5. c
   a. formed the theory that all living things are made up of cells
   b. made important observations about a thin slice of cork that he studied
   c. invented the microscope
6. The first scientists to make test-tube models of the nucleic acids, DNA and RNA, were — 6. a
   a. Dr. Ochoa and Dr. Kornberg
   b. Schwann and Schleiden
   c. Howard Florey and Ernest Chain
7. A plant cell has a covering around its cell membrane called — 7. a
   a. a cell wall
   b. a nucleus
   c. RNA

8. Groups of cells that work together are called
   a. cytoplasms
   b. diatoms
   c. tissues

8. __ __ c __ __

9. The growth and reproduction of a cell is directed by the
   a. nucleus
   b. cytoplasm
   c. cell membrane

9. __ __ a __ __

10. An ameba is
   a. made up of many cells
   b. a one-celled organism
   c. a many-celled organism

10. __ __ b __ __

11. Fertilization in chickens takes place
   a. when the nucleus of the sperm cell joins with the nucleus of an egg cell
   b. only after a single egg cell has divided many times
   c. when cell nuclei, produced by pollen grains, join ovule nuclei

11. __ __ a __ __

12. Rooster sperm cells are produced in organs called
   a. chrysalids
   b. ovaries
   c. testes

12. __ __ c __ __

13. Scientific study of early development of living things is called
   a. genetics
   b. germination
   c. embryology

13. __ __ c __ __

14. Dr. George Beadle and Dr. Edward Tatum observed and studied
   a. the life activities of a sponge
   b. how the stomach digests food
   c. red bread mold spores which had been exposed to X rays

14. __ __ c __ __

15. Growth hormones found in plants are called
   a. auxins
   b. endoderms
   c. stamens

15. __ __ a __ __

16. The arteries
   a. carry blood away from the heart
   b. carry blood back to the heart from the capillaries
   c. are the thinnest blood vessels in the body

16. __ __ a __ __

17. A British scientist who discovered that penicillin can kill certain germs was
   a. William Beaumont
   b. Michael Faraday
   c. Alexander Fleming

17. __ __ c __ __

18. The glands from which saliva flows are the
   a. pituitary glands
   b. salivary glands
   c. adrenal glands

18. __ __ b __ __

19. The part of your brain that enables you to think and decide answers to these questions is the
   a. cerebellum
   b. cerebrum
   c. adrenal glands

19. __ __ b __ __

20. Ivan Pavlov
   a. studied the learning process
   b. studied the uses of atomic energy
   c. invented the stethoscope

20. __ __ a __ __

21. A disease caused by the lack of certain vitamins or an essential nutrient is called
   a. an infectious disease
   b. a degenerative disease
   c. a deficiency disease

21. __ __ c __ __

22. A physician who believed that sickness is the result of a body imbalance of fire, air, water, and earth was
   a. Hippocrates
   b. Galen
   c. Jenner

22. __ __ b __ __

23. Chemical substances that develop in your blood to help fight off infections are
   a. antibodies
   b. antibiotics
   c. antiseptics

23. __ __ a __ __

24. A person sensitive to a specific substance is said to be
   a. mutant
   b. deficient
   c. allergic

24. __ __ c __ __

25. Louis Pasteur's experiments with microorganisms enabled him — 25. **a**
   a. to form the germ theory of disease
   b. to find a vaccine that makes most people immune to polio
   c. to use a chemical to kill bacteria

Fill in the correct word or words for each sentence.

organism   virus   bacteria   theory   probability theory

1. A **theory** tries to show the connection among many facts.
2. **Probability theory** is used by scientists to make predictions.
3. All the systems working together make up an organized living system, or **organism**.
4. A **virus** is a very tiny bit of protein that can be cultured only inside a living cell.
5. Tuberculosis and diptheria are diseases caused by **bacteria**.

Unit 6: The World of Chemistry

Select the best answer to complete each statement.
Write the letter of the answer in the space at the right.

1. Physical properties are those properties that — 1. **b**
   a. cannot be described
   b. can be observed without the substance changing into something else
   c. are the same as chemical properties
2. Lavoisier said that when something burns it combines with — 2. **b**
   a. phlogiston
   b. oxygen
   c. water
3. A snowflake is a — 3. **b**
   a. liquid
   b. solid
   c. gas

4. The boiling point of water at sea level is 4. __ __ c __ __
    a. 32° F.
    b. 100° F.
    c. 212° F.

5. If a substance has a definite shape it is a 5. __ __ b __ __
    a. liquid
    b. solid
    c. gas

6. If you place a lump of sugar in a cup of water, you have a 6. __ __ b __ __
    a. gas
    b. solution
    c. chemical reaction

7. Cold water will dissolve 7. __ __ a __ __
    a. less salt than hot water
    b. more salt than hot water
    c. the same amount of salt as hot water

8. If you keep adding salt to a cup of water you will have 8. __ __ b __ __
    a. a chemical reaction
    b. a saturated solution
    c. an element

9. Crystals are found in 9. __ __ c __ __
    a. glass
    b. water
    c. salt

10. A "seed" crystal will grow more rapidly in 10. __ __ c __ __
    a. a saturated solution
    b. air
    c. a supersaturated solution

11. The lightest element found in nature is 11. __ __ b __ __
    a. oxygen
    b. hydrogen
    c. uranium

12. A substance that can not be broken down into other substances is 12. __ __ b __ __
    a. a solution
    b. an element
    c. a crystal

13. Helium and hydrogen make up
    a. a small percent of the universe
    b. about 99 % of the universe
    c. about 50 % of the universe

13. __ __ b __ __

14. In the universe there are
    a. nearly 100 elements
    b. more than 100 elements
    c. about 50 elements

14. __ __ b __ __

15. The building blocks of all the matter in the universe are
    a. molecules
    b. compounds
    c. atoms

15. __ __ c __ __

16. An electron is
    a. positively charged
    b. negatively charged
    c. neutral

16. __ __ b __ __

17. The orbit nearest the nucleus in any atom holds no more than
    a. 1 electron
    b. 8 electrons
    c. 2 electrons

17. __ __ c __ __

18. When atoms combine, they form
    a. a nucleus
    b. molecules
    c. a neutron

18. __ __ b __ __

19. Atoms that have lost or gained electrons are called
    a. ions
    b. protons
    c. neutrons

19. __ __ a __ __

20. The formula for water is
    a. $H_2 O_2$
    b. HO_2
    c. H_2O

20. __ __ c __ __

Fill in the correct word for each sentence.

atom properties soluble nucleus supersaturated

1. A substance has both physical and chemical **properties**.
2. A **supersaturated** solution contains more of a soluble substance than can be held in a saturated solution.
3. A substance is **soluble** if it dissolves in another substance.
4. The smallest piece of any kind of matter is called an **atom**.
5. The atomic mass is the total number of particles in the **nucleus** of the atom.

Unit 7: Probing the Atmosphere

Select the best answer to complete each statement.
Write the letter of the answer in the space at the right.

1. The United States Weather Bureau now predicts the weather for — 1. **c**
   a. 3 months in advance
   b. only 3 days in advance
   c. 30 days in advance
2. Cold air — 2. **b**
   a. is less dense than warm air
   b. is more dense than warm air
   c. has the same density as warm air
3. Most of the earth's air is — 3. **c**
   a. oxygen
   b. carbon dioxide
   c. nitrogen
4. The layer of the atmosphere nearest the earth is called the — 4. **a**
   a. troposphere
   b. tropopause
   c. stratosphere
5. The jet streams are found in the — 5. **c**
   a. exosphere
   b. ionosphere
   c. troposphere

6. Atmospheric pressure at sea level is
   a. 10.5 pounds per square inch
   b. 14.7 pounds per square inch
   c. 16.2 pounds per square inch

6. __ __ b __ __

7. A thermograph is used to measure
   a. wind velocity
   b. heat
   c. barometric pressure

7. __ __ b __ __

8. Atmospheric pressure is measured by
   a. anemometers
   b. barometers
   c. hygrometers

8. __ __ b __ __

9. There is almost no weather in the
   a. troposphere
   b. tropopause
   c. stratosphere

9. __ __ c __ __

10. Cirrus clouds
    a. are thin and curly
    b. are light and puffy
    c. look like gray sheets

10. __ __ a __ __

11. Relative humidity is measured by a
    a. barometer
    b. hygrometer
    c. anemometer

11. __ __ b __ __

12. About 10 inches of snow is equal to the amount of water in
    a. 10 inches of rain
    b. 1 inch of rain
    c. 5 inches of rain

12. __ __ b __ __

13. The falling of rain or snow is called
    a. precipitation
    b. visibility
    c. relative humidity

13. __ __ a __ __

14. A whirling mass of air with a funnel-shaped cloud is called
    a. a hurricane
    b. a tornado
    c. a cold front

14. __ __ b __ __

15. Visibility can be measured with — 15. c
    a. radar
    b. hygrometers
    c. transmissometers

16. Isobars are used on a weather map to show — 16. c
    a. fronts
    b. wind direction
    c. atmospheric pressure

17. When a warm air mass takes the place of a cold air mass, a — 17. c
    a. cold front occurs
    b. stationary front occurs
    c. warm front occurs

18. Weather ballons are inflated with — 18. b
    a. radiosonde
    b. helium
    c. air

19. Forecasters can now make forecasts in terms of probability by using — 19. c
    a. gravimeters
    b. IGY
    c. computers

20. Information about the weather is collected — 20. c
    a. only by expert forecasters
    b. only at weather stations
    c. with the help of many volunteer observers

Fill in the correct word for each sentence.

millibar   radar   anemometer   exosphere   radiosondes

1. The **exosphere** is the highest layer of the earth's atmosphere.
2. An **anemometer** is used to find out how fast the wind is moving.
3. **Radar** is used to locate storms and follow their movements.
4. A **millibar** is another unit for measuring atmospheric pressure.
5. **Radiosondes** are attached to balloons to gather information about weather in the upper levels of the atmosphere.

Unit 8: *Probing Outer Space*

Select the best answer to complete each sentence.
Write the letter of the answer in the space at the right.

1. The hot air balloon built by the Montgolfier brothers floated into the atmosphere because — 1. __ __ a __ __
   a. the warm air in the balloon had less weight than the air outside the balloon
   b. the warm air in the balloon had more weight than the air outside the balloon
   c. the balloon was forced up by the thrust of a rocket engine
2. The force of a rocket engine is called — 2. __ __ c __ __
   a. gravity
   b. a centrifuge
   c. thrust
3. Russian space pilots are called — 3. __ __ b __ __
   a. astronauts
   b. cosmonauts
   c. satellites
4. Tiros spacecraft carry television cameras to take pictures of — 4. __ __ c __ __
   a. the sun
   b. the moon
   c. clouds
5. When a spacecraft goes into orbit, the spacecraft is called — 5. __ __ b __ __
   a. a test plane
   b. a satellite
   c. a rocket
6. A force equal to the normal force of the earth's gravity is — 6. __ __ a __ __
   a. a G force
   b. a gram
   c. an E force
7. Certain foods may be preserved for long space flights by — 7. __ __ b __ __
   a. exposing them to carbon dioxide
   b. irradiation
   c. irrigation

8. Algae may be useful to men living in spacecraft because
    a. algae give off carbon dioxide
    b. algae give off hydrogen
    c. algae give off oxygen and use carbon dioxide

8. ___ ___ c ___ ___

9. Science has enabled man to build a machine whose circular motion produces a force that is similar to the force of the earth's gravity. This machine is called
    a. a convection
    b. a centrifuge
    c. a computer

9. ___ ___ b ___ ___

10. Dr. Robert Goddard was one of the first scientists
    a. to place instruments in rockets
    b. to fly a plane alone across the Atlantic Ocean
    c. to ride a rocket-propelled test sled that reached a speed of 421 miles per hour

10. ___ ___ a ___ ___

11. An American balloonist, Captain H. C. Gray,
    a. furnished important evidence for scientists about the temperature of the atmosphere
    b. did experiments to find out how altitude affects the rate of heartbeat
    c. filled bottles with air from the atmosphere and brought them back to earth to be studied

11. ___ ___ a ___ ___

12. Many of the first balloons that were used to explore the atmosphere were filled with
    a. nitrogen
    b. unheated air
    c. hydrogen

12. ___ ___ c ___ ___

13. The weightless feeling that astronauts experience during their flights in space is due to
    a. the lack of gravity
    b. an increase in G forces
    c. high G forces

13. ___ ___ a ___ ___

14. We are protected from many of the deadly rays found in space by the protective shield of
    a. the earth's atmosphere
    b. sunshine
    c. the food we eat

14. ___ ___ a ___ ___

15. Newton's Third Law of Motion, which helps to explain the action-reaction principle of rockets, states that
    a. an object at rest remains at rest, or if in motion continues in motion in a straight line and at the same speed, unless an outside force acts on it
    b. for every action, there is always another reaction that is equal to it
    c. the rate at which the speed of an object changes depends on two things: the mass of the object and the force behind it

15. _ _ b _ _

16. Satellites that are launched to orbit the earth do not continue off in space in a straight line because
    a. they are held in orbit by the earth's force of gravity
    b. we cannot build rockets that are capable of traveling in a straight line
    c. they are held in orbit around the earth by the clouds that surround the earth

16. _ _ a _ _

17. The Explorer and Vanguard spacecraft
    a. collect information about radiation, meteoroids, and temperatures in space
    b. collect pictures of the moon's surface
    c. send television programs from one continent to another

17. _ _ a _ _

18. From the deep space probes launched by Russia and the United States, we have evidence that
    a. the moon has air and water
    b. the moon does not have any air, and probably does not have a magnetic field
    c. the moon's surface is covered by clouds, moisture, and various other liquids

18. _ _ b _ _

19. A horizontal speed of about 7 miles a second, which enables a spacecraft to escape the earth's gravity, is called
    a. orbit speed
    b. artificial gravity
    c. escape speed

19. _ _ c _ _

20. Heat is not found in space because
    a. the energy from the sun is not capable of traveling through distances in space
    b. there is nothing in space that is capable of absorbing any of the sun's energy
    c. the sun shines only on planets

20. _ _ b _ _

Fill in the correct word or words for each sentence.

Auguste Piccard solar flare Robert Goddard

action-reaction space stations

1. **Robert Goddard** developed the first liquid-fuel rocket.
2. **Auguste Piccard** learned about cosmic rays in the stratosphere.
3. Rocket engines work on the principle of **action-reaction**.
4. A **solar flare** is an eruption from the sun which can send dangerous rays of atomic particles into space.
5. **Space stations** may be built to enable spacecraft to refuel in space.

Unit 9: *Probing the Oceans*

Select the best answer to complete each statement.
Write the letter of the answer in the space at the right.

1. Man can now skin dive by using — 1. **b**
   a. a bathysphere
   b. an aqualung
   c. a convection
2. When scientists wish to dive very far below the surface of the ocean, they are faced with the problem of — 2. **a**
   a. the great pressure exerted by the water
   b. sword fish
   c. very hot water
3. The shallowest parts of the oceans are — 3. **a**
   a. the continental shelves
   b. the slopes
   c. the floors
4. When scientists descend to great depths in a bathyscaphe, they keep the pressure of the air in the cabin — 4. **c**
   a. the same as the pressure of the water outside the cabin
   b. at 30 pounds per square inch
   c. at 15 pounds per square inch

5. Sound vibrations travel
   a. slower in water than in air
   b. faster in water than in air
   c. at the same speed in air as in water

5. — — b — —

6. The deepest parts of the ocean are called the
   a. slopes
   b. floors
   c. continental shelves

6. — — b — —

7. A fathom is
   a. 6 feet
   b. 3 feet
   c. 12 feet

7. — — a — —

8. A salinometer is used to
   a. get samples of water from the ocean
   b. find the amount of salt in a sample of ocean water
   c. obtain samples of sediment

8. — — b — —

9. The ocean environment
   a. never changes
   b. changes every few thousand years
   c. is constantly changing

9. — — c — —

10. The density of sea water depends mostly on the
    a. color of the water
    b. amount of salts dissolved in the water
    c. ocean floor

10. — — b — —

11. Tropical waters tend to be
    a. low in salt content
    b. high in salt content
    c. cold

11. — — b — —

12. The process causing movement of water is
    a. convection
    b. salinity
    c. gravity

12. — — a — —

13. Scientists believe that
    a. life began in the lowest depths of the sea
    b. life did not begin in the lowest depths of the sea
    c. life did not begin in the surface waters

13. — — b — —

14. A diatom is a
    a. one-celled green plant
    b. fish
    c. fossil

14. a

15. The basic food of the ocean is
    a. seaweed
    b. plankton
    c. holdfasts

15. b

16. A diatom reproduces by
    a. laying eggs
    b. dividing to form two cells
    c. dividing to form four cells

16. b

17. Seaweed plants have
    a. roots
    b. strong stems
    c. holdfasts

17. c

18. Farming the seas is called
    a. agriculture
    b. aquaculture
    c. oceanography

18. b

19. Whales are
    a. fish
    b. reptiles
    c. mammals

19. c

20. Minerals are found on the ocean floor in the form of
    a. seaweed
    b. holdfasts
    c. nodules

20. c

Fill in the correct word for each sentence.

salinity   larvae   plankton   oceanography   bathyscaphe

1. The **bathyscaphe** is a deep-sea diving balloon that enables scientists to plunge to a depth of almost seven miles.

2. The study of oceans and seas is called **oceanography**.

3. The saltiness of water is called its **salinity**.

4. The tiny green plants of the ocean and certain small animals that feed on them are called **plankton**.

5. The fertilized eggs of the female oyster hatch into tiny **larvae**.

Do You Remember? — Units 6, 7, 8, 9

Select the best answer to complete each statement.
Write the letter of the answer in the space at the right.

1. Everything in the universe is made from among the more than one hundred different substances called — 1. **b**
   a. chemical properties
   b. elements
   c. solutions

2. The lightest of all known elements is — 2. **b**
   a. oxygen
   b. hydrogen
   c. helium

3. Every substance is in one of — 3. **b**
   a. 2 states
   b. 3 states
   c. 4 states

4. At sea level the boiling point of water is — 4. **c**
   a. 112° F.
   b. 200° F.
   c. 212° F.

5. When atoms combine, they form — 5. **c**
   a. solutions
   b. nucleus
   c. molecules

6. The positively charged particle in an atom's nucleus is a — 6. **c**
   a. neutron
   b. electron
   c. proton

7. The formula for carbon dioxide is 7. ___ ___ a ___ ___
   a. CO_2
   b. CO
   c. C_2O

8. The total amount of air around the earth is called the 8. ___ ___ a ___ ___
   a. atmosphere
   b. stratosphere
   c. exosphere

9. The pressure of the atmosphere at sea level is 9. ___ ___ b ___ ___
   a. 15.8 pounds per square inch
   b. 14.7 pounds per square inch
   c. 18.4 pounds per square inch

10. Atmospheric pressure is measured by 10. ___ ___ b ___ ___
    a. anemometers
    b. barometers
    c. gravimeters

11. The atmosphere is divided into 11. ___ ___ c ___ ___
    a. 2 layers
    b. 3 layers
    c. 5 layers

12. The highest layer of the earth's atmosphere is called the 12. ___ ___ a ___ ___
    a. exosphere
    b. stratosphere
    c. troposphere

13. The scientist known as the father of modern chemistry is 13. ___ ___ b ___ ___
    a. Robert M. White
    b. Antoine Lavoisier
    c. Robert H. Goddard

14. Water evaporates faster in air that is 14. ___ ___ c ___ ___
    a. cold
    b. very cold
    c. warm

15. Clouds that look like gray sheets are called 15. ___ ___ c ___ ___
    a. cumulus clouds
    b. cirrus clouds
    c. stratus clouds

16. A force called a G force
    a. is the same thing as weightlessness
    b. is a force equal to the normal force of the earth's gravity
    c. affects only astronauts

16. — — b — —

17. The first liquid-fuel rocket was developed by
    a. Robert Goddard
    b. Colonel Stapp
    c. Auguste Piccard

17. — — a — —

18. Tiny green plants that may be used to produce oxygen inside spacecraft are called
    a. penicillin
    b. plankton
    c. algae

18. — — c — —

19. During lift-off and re-entry, astronauts experience
    a. the lack of gravity
    b. G forces
    c. the danger of solar flares

19. — — b — —

20. The American who is called the "father of oceanography," is
    a. Robert M. White
    b. Matthew Fontaine Maury
    c. Auguste Piccard

20. — — b — —

21. The deepest parts of the ocean are the
    a. floors
    b. slopes
    c. continental shelves

21. — — a — —

22. The basic food of the sea is
    a. plankton
    b. seaweed
    c. nodules

22. — — a — —

23. Free diving is possible because of the
    a. bathysphere
    b. aqualung
    c. holdfasts

23. — — b — —

24. The process that causes currents in the water is called
    a. convection
    b. salinity
    c. conduction

24. — — a — —

25. The depth of the ocean is measured in
   a. yards
   b. feet
   c. fathoms

25. c

Fill in the right word or words for each sentence.

salinometer   anemometer   multistage rockets   elements   hygrometer

1. All matter is made of **elements**.
2. An **anemometer** is used to measure wind speed.
3. A **hygrometer** is used to measure relative humidity.
4. A **salinometer** is used to find the amount of salt in a sample of water.
5. **Multistage rockets** are used to reach the speed of 18,000 miles an hour needed to place spacecraft in orbit.

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John F. Rider Publisher, Inc., 116 West 14th St., New York, N.Y., 10011
Ronald Press Co., 15 East 26th St., New York, N.Y., 10010
Roy Publishers, 30 East 74th St., New York, N.Y., 10021
St. Martin's Press, 175 Fifth Ave., New York, N.Y., 10010
Scholastic Magazines, 902 Sylvan Ave., Englewood Cliffs, N.J., 17631
Science Service, Inc., 1719 N St., N.W., Washington, D.C., 20006
William R. Scott, Inc., 8 West 13th St., New York, N.Y., 10011
Scott, Foresman and Co., 433 E. Erie St., Chicago, Ill.
Charles Scribner's Sons, 597 Fifth Ave., New York, N.Y., 10017
Shorewood Publishing Co., Inc., 304 East 45th St., New York, N.Y., 10017
Silver Burdett Co., Columbia Rd. and Park Ave., Morristown, N.J., 07960
Simon and Schuster, Inc., 630 Fifth Ave., New York, N.Y., 10020
L. W. Singer Co., Inc., 249–259 West Erie Blvd., Syracuse, N.Y., 13202
Spencer Press, Inc., 179 North Michigan Ave., Chicago, Ill., 60601
Sterling Publishing Co., Inc., 419 Fourth Ave., New York, N.Y., 10016
University of Chicago Press, 5750 Ellis Ave., Chicago, Ill., 60637
University of Michigan Press, 615 East University, Ann Arbor, Mich., 48103
University of Minnesota Press, 2307 University Ave., S.E., Minneapolis, Minn., 55414
D. Van Nostrand Co., Inc., 120 Alexander St., Princeton, N.J., 08540
Viking Press, 625 Madison Ave., New York, N.Y., 10022
Franklin Watts, Inc., 575 Lexington Ave., New York, N.Y., 10022
Albert Whitman & Co., 560 West Lake St., Chicago, Ill., 60606
H. W. Wilson Co., 950 University Ave., New York, N.Y., 10052
World Publishing Co., 119 West 57th St., New York, N.Y., 10019

Directory of Film and Filmstrip Sources

1. GUIDES

Audio-Visual Communication Review, published bimonthly by the Department of Audio-Visual Instruction, Washington, D.C.
Blue Book of Audio-Visual Materials (annual), Educational Screen, Inc., 64 E. Lake St., Chicago, Ill.
A Directory of 16mm Film Libraries, U.S. Department of Health, Education and Welfare; U.S. Government Printing Office, Washington, D.C.
Education Film Guide (annual), The H. W. Wilson Co., 950 University Ave., New York, N.Y.
Educators Guide to Free Films (annual), Educators Progress Service, Randolph, Wisc.
Filmstrip Guide (annual), The H. W. Wilson Co., 950 University Ave., New York, N.Y.
Modern Index and Guide to Free Educational Films from Industry (annual), Modern Talking Picture Service, Inc., 3 E. 54th St., New York, N.Y.
U.S. Government Films for Public Educational Use, 1955, Office of Education, U.S. Department of Health, Education and Welfare; U.S. Government Printing Office, Washington, D.C.
U.S. Government Films for Schools and Colleges (annual), United World Films Inc., 1445 Park Ave., New York, N.Y.

2. DISTRIBUTORS OF AUDIO-VISUAL AIDS

American Cancer Society, Inc., 521 W. 57th St., New York, N.Y.

American Heart Association, Inc., Film Library, 44 E. 23rd St., New York, N.Y. (Films also available from local heart associations.)

American Museum of Natural History, Slide Library, Central Park West at 79th St., New York, N.Y.

American Red Cross (Contact nearest American Red Cross chapter.)

Association Films, Inc., 347 Madison Ave., New York, N.Y. (Branch offices in Ridgefield, N.J.; Dallas, Tex.; San Francisco, Calif.; La Grange, Ill.)

Bell Telephone System (Contact local Bell Telephone Co. offices for address of regional distributor; or contact the American Telephone and Telegraph Co., Motion Picture Section, 195 Broadway, New York, N.Y.)

Blackhawk Films, 1235 W. 5th St., Davenport, Ia.

Better Vision Institute, Inc., 230 Park Ave., New York, N.Y.

University of California, University Extension, Educational Film Sales Dept., Los Angeles, Calif.

University of Southern California, Audio-Visual Services, Dept. of Cinema; University Park, Los Angeles, Calif.

National Film Board of Canada, 680 Fifth Ave., Suite 819, New York, N.Y.

Carousel Films, Inc., 1501 Broadway, New York, N.Y.

Churchill-Wexler Film Productions, 801 N. Seward St., Los Angeles, Calif.

Coronet Instructional Films, 65 E. South Water St., Chicago, Ill.

DeKalb Agricultural Assn., Inc., Educational Dept., 310 N. 5th St., DeKalb, Ill.

Walt Disney Productions, Educational Film Div., 500 S. Buena Vista Ave., Burbank, Calif. (Branch office in New York, N.Y.)

E. I. duPont de Nemours & Co., Inc., Motion Picture Distribution, Advertising Dept., Wilmington, Del.

Encyclopaedia Britannica Films, 1150 Wilmette Ave., Wilmette, Ill. (Branch offices in Hollywood, Calif.; Atlanta, Ga.; Skokie, Ill.; New York, N.Y.; Dallas, Tex.; Toronto, Ontario, Canada.)

Educational Testing Service, 20 Nassau St., Princeton, N.J. (Branch office in Los Angeles, Calif.)

Film Associates of California, 11014 Santa Monica Blvd., Los Angeles, Calif.

Handel Film Corp., 6926 Melrose Ave., Los Angeles, Calif.

International Film Bureau, Inc., 57 E. Jackson Blvd., Chicago, Ill. (Branch office in Ottawa, Ontario, Canada.)

Indiana University, Audio-Visual Center, Bloomington, Ind.

Life Magazine Filmstrip Div., Time and Life Bldg., Rockefeller Center, New York, N.Y.

McGraw-Hill Book Company, Inc., Text-Film Dept., 330 W. 42nd St., New York, N.Y.

Michigan Dept. of Conservation, Film Loan Service, Lansing, Mich.

Michigan State University, Co-operative Extension Service. Agricultural Hall, Room 10, East Lansing, Mich.

University of Minnesota, Audio-Visual Education Service, Westbrook Hall, Minneapolis, Minn.

Metropolitan Life Insurance Company, 1 Madison Ave., New York, N.Y. (Offices in San Francisco, Calif. and Ottawa, Ontario, Canada.)

Missouri Conservation Commission, Film Loan Library, Monroe Bldg., Jefferson City, Mo.

Modern Talking Picture Service, Inc., Headquarters Office, 3 E. 54th St., New York, N.Y. (Film libraries in other cities throughout the U.S., including Anchorage, Alaska, and Honolulu, Hawaii.)

University of Nebraska, Bureau of Audio-Visual Aids, Extension Div., Lincoln, Nebr.

NET Film Service, Audio-Visual Center, Indiana University, Bloomington, Indiana

The National Foundation, Public Information Dept., 800 Second Ave., New York, N.Y.

National Tuberculosis Assn., 1790 Broadwav, New York, N.Y. (Films loaned through state and local tuberculosis associations.)

State University of New York, College of Forestry at Syracuse University, Dept. of Forest Extension, Syracuse, N.Y.

Ohio Division of Wildlife, Dept. of Natural Resources, 1500 Dublin Rd., Columbus, Ohio

Oregon State System of Higher Education, Dept. of Visual Instruction, General Extension Division, 131 Coliseum, Corvallis, Ore.

Pennsylvania State University, Audio-Visual Aids Library, University Park, Pa.

Shell Oil Co., Public Relations Dept., 50 W. 50th St., New York, N.Y.

Sterling Movies U.S.A., 100 W. Monroe St., Chicago, Ill.

U.S. Forest Service, Dept. of Interior, Washington 25, D.C. (Contact film library of your state university extension division or regional office of the U.S. Forest Service.)

United World Films, Inc., 1445 Park Ave., New York, N.Y. (Branch offices in Los Angeles, Calif.; Miami, Fla.; Atlanta, Ga.; Chicago, Ill.; Portland, Ore.; Dallas, Tex.)

World Wide Pictures, P.O. Box 1055, Sherman Oaks, Calif.

Directory of Science Materials Supply Houses

American Electronic Laboratories, Inc., 121 N. 75th St., Philadelphia, Pa.

American Hospital Supply Corp., 40–05 168th St., Flushing, Queens, N.Y.; or Evanston, Ill. (blood-typing serums, standard supplies)

American Optical Co., Buffalo, N.Y. (optical instruments)

American Type Culture Collection, 2112 M St., N.W., Washington, D.C. (bacteria)

Bausch & Lomb Optical Co., 635 St. Paul St., Rochester, N.Y. (optical instruments)

James G. Biddle Co., 1316 Arch St., Philadelphia, Pa. (scientific instruments)

Biological Research Products Co., 243 W. Root St., Stockyards Station, Chicago, Ill. (fresh and preserved mammalian specimens and organs)

Burgess Battery Co., Freeport, Ill. (dry cells)

California Biological Service, 1612 W. Glenoaks Blvd., Glendale, Calif.

California Botanical Materials Co., 861 E. Columbia Ave., Pomona, Calif.

Cambosco Scientific Co., 37 Antwerp St., Brighton, Mass.

Carolina Biological Supply Co., Elon College, N.C.

Central Scientific Co., 1700 W. Irving Park Rd., Chicago, Ill.

Chemical Rubber Co., 2310 Superior Ave., Cleveland, Ohio

Corning Glass Works, Corning, N.Y. (glassware)

Denoyer-Geppert Co., 5235 Ravenswood Ave., Chicago, Ill. (models, charts, slides, microscopes)

Difco Laboratories, Inc., 920 Henry St., Detroit 1, Michigan (reagents, culture media)

Dow Chemical Co., Midland, Mich. (chemicals)

Eastman Kodak Co., 343 State St., Rochester, N.Y. (photographic supplies and equipment)

Edmond Scientific Co., 99 E. Gloucester Pike, Barrington, N.J. (scientific instruments)

Fisher Scientific Co., Forbes Ave., Pittsburgh, Pa. (chemicals, laboratory appliances)

General Biochemicals, Inc., 677 Laboratory Park, Chagrin Falls, Ohio (chemicals)

General Biological Supply House, Inc. (Turtox), 8200 S. Hoyne Ave., Chicago, Ill.

Graf-Apsco Co., 5868 Broadway, Chicago, Ill. (microscopes)

Kimble Glass, P.O. Bo;

Lederle Laboratories, Div. of American Cyanamid Co., Middletown Rd., Pearl River, N.Y. (chemicals)

E. Leitz, Inc., 468 Park Ave., New York, N.Y. (optical instruments)

Los Angeles Biological Laboratory, Woods Hole, Mass. (living and preserved materials)

Merck & Co., Inc., 126 E. Lincoln Ave., Rahway, N.J. (chemicals)

Monsanto Chemical Co., 1700 S. Second St., St. Louis, Mo. (chemicals)

National Biological Supply Co., Inc., 230 W. Superior St., Chicago, Ill.

National Instruments Laboratories, Inc., 828 Evarts St., N.E., Washington, D.C.

New York Scientific Supply Co., Inc., 28 W. 30th St., New York, N.Y.

Nutritional Biochemicals Corp., 21010 Miles Ave., Cleveland, Ohio (chemicals)

A. J. Nystrom & Co., Inc., 3333 Elston Ave., Chicago, Ill. (charts, models)

cientific Supplies, Inc., 69 W. 23rd St., New York, N.Y. (microscopes, microslides, stains)

E. H. Sargent and Co., 4647 W. Foster Ave., Chicago, Ill.

E. H. Sheldon Equipment Co., 101 Park Ave., Rm. 538, New York, N.Y. (laboratory furniture)

Spitz Laboratories, Yorklyn, Dela. (shadowboxes, plasteria)

Sprague-Dawley, Inc., P.O. Box 2071, Madison, Wisc. (laboratory rats)

Standard Scientific Supply Corp., 808 Broadway, New York, N.Y.

Testa Manufacturing Co., 418 S. Pecan St., Los Angeles, Calif. (microscopes)

Triarch Botanical Products, Ripon, Wisc. (botanical microslides)

United Scientific, Inc., 66 Needham, Newton, Mass. (optical instruments)

Wards Natural Science Establishment, Inc., P.O. Box 1712, Roc ester, N.Y.

Welch Scientific Co., 1515 Sedgwick St., Chicago, Ill. (scientific apparatus)

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Cells, tissues, and organisms—Drawings on pages 25-27 and 43
Photographs on pages 22-25, 28, 29, 33, 34, 36, 37, 41, and 43
Diagrammatic drawings on pages 26, 29, 38, 41, and 43
Illustrations of activities on pages 31, 32, 35, and 42

Conquering disease—Drawings on pages 125, 126, 129, 130, 139, 147, and 163
Photographs on pages 122-124, 126, 127, 131-136, 142, 149-151, 153, 156, 158, and 161
Diagrammatic drawings on pages 145 and 155
Illustrations of activities on pages 128, 140, 141, and 144

Probing outer space—Drawings on pages 264-266, 272, 302, 303, and 309
Photographs on pages 262-264, 268, 269, 271, 274, 276, 283-286, 289-291, 293, 300, and 304
Diagrammatic drawings on pages 281, 282, 294, and 297
Illustrations of activities on pages 273, 275, 277, 279, 287, 292, 296, 299, and 308

IN THE BACK OF THE TEXT YOU WILL FIND:

An illustrated "Dictionary of Science Words"
A "Dictionary of Scientists"
A "Checklist of Science Activities"
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